

AD-A271 372



REPORT DOCUMENTATION PAGE

Form Approved

OMB No. 0704-0188

It is estimated to average 1 number response, including the time for reviewing instructions, searching existing data sources, gathering and reviewing the collection of information, sending comments regarding this burden estimate or any other aspect of this burden estimate, including this burden estimate, Washington Headquarters services, and providing for information, operations and reports, 1215 Jefferson Road to the Office of Management and Budget, Paperwork Project (0704-0188), Washington, DC 20503.

2. REPORT DATE
11/00/89

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
ALTERNATIVES ASSESSMENT OF INTERIM RESPONSE ACTIONS FOR OTHER CONTAMINATION SOURCES, M-1 SETTLING BASINS, ROCKY MOUNTAIN ARSENAL VERSION 3.1, FINAL

5. FUNDING NUMBERS

6. AUTHOR(S)

DAAA15 88 D 0022

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

WOODWARD-CLYDE CONSULTANTS

8. PERFORMING ORGANIZATION
REPORT NUMBER

90002R05

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

ROCKY MOUNTAIN ARSENAL (CO.). PMRMA

10. SPONSORING / MONITORING
AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

THIS DOCUMENT DESCRIBES THE PROCESS AND RESULTS OF THE ALTERNATIVES ASSESSMENT CONDUCTED FOR THE M-1 SETTLING BASINS. THESE THREE BASINS ARE LOCATED IN THE SOUTH PLANTS AREA AND ARE A DIRECT SOURCE OF AS CONTAMINATION TO THE GROUND WATER. THE GOAL OF THIS ASSESSMENT IS TO EVALUATE ALTERNATIVES BASED UPON SUCH FACTORS AS 1) THE PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT, 2) MITIGATION OF THE THREAT TO HUMAN HEALTH, AND 3) COST.

THE ASSESSMENT IS DIVIDED INTO THE FOLLOWING SECTIONS:

1. INTRODUCTION
2. SITE BACKGROUND AND THE RESULTS OF CURRENT AND PREVIOUS INVESTIGATIONS
3. IDENTIFICATION AND EVALUATION OF INTERIM ACTION TECHNOLOGIES
4. DEVELOPMENT AND EVALUATION OF ALTERNATIVES
5. COST ESTIMATES
6. CONCLUSIONS.

THE PREFERRED TECHNOLOGIES ARE 1) IN-SITU VITRIFICATION AND 2) CHEMICAL

14. SUBJECT TERMS
IRA L, COST, SOIL, GROUNDWATER

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION
UNCLASSIFIED18. SECURITY CLASSIFICATION
OF THIS PAGE19. SECURITY CLASSIFICATION
OF ABSTRACT

20. LIMITATION OF ABSTRACT

DTIC
ELECTE
OCT 21 1993
S B D

**FINAL ALTERNATIVES ASSESSMENT
OF
INTERIM RESPONSE ACTIONS
FOR OTHER CONTAMINATION SOURCES
M-1 SETTLING BASINS
ROCKY MOUNTAIN ARSENAL
NOVEMBER 1989
CONTRACT NO. DAAA15-88-D-0022/0002
VERSION 3.1**

Prepared by:

WOODWARD-CLYDE CONSULTANTS

Prepared for:

**U.S. ARMY PROGRAM MANAGER'S OFFICE
FOR ROCKY MOUNTAIN ARSENAL CONTAMINATION CLEANUP**

93-24965



**Rocky Mountain Arsenal
Information Center
Commerce City, Colorado**

**THE USE OF TRADE NAMES IN THIS REPORT DOES NOT CONSTITUTE AN OFFICIAL
ENDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL PRODUCTS. THE REPORT
MAY NOT BE CITED FOR PURPOSES OF ADVERTISEMENT.**

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1.0 INTRODUCTION	1-1
1.1 PURPOSE OF THE INTERIM RESPONSE ACTION (IRA) ALTERNATIVE ASSESSMENT DOCUMENT	1-1
1.2 IRA CANDIDATE SELECTION CRITERIA	1-1
1.3 REPORT ORGANIZATION	1-3
2.0 SITE BACKGROUND AND INTERIM ACTION INVESTIGATION	2-1
2.1 SITE DESCRIPTION	2-1
2.1.1 Location	2-1
2.1.2 History	2-1
2.1.3 Geology	2-2
2.1.4 Hydrology	2-5
2.1.5 Previous Investigations	2-7
2.2 NATURE AND EXTENT OF CONTAMINATION	2-9
2.2.1 Soils	2-9
2.2.2 Groundwater	2-9
2.3 CONTAMINANT FATE AND TRANSPORT	2-14
2.3.1 Organics Fate and Transport	2-14
2.3.2 Metals Fate and Transport	2-15
2.4 APPLICABLE SITE STANDARDS	2-16
2.5 EVALUATION BASIS FOR INTERIM RESPONSE ACTIVITY	2-17
3.0 IDENTIFICATION AND EVALUATION OF INTERIM ACTION TECHNOLOGIES	3-1
3.1 INTERIM RESPONSE ACTION OBJECTIVE	3-1
3.2 IDENTIFICATION AND EVALUATION OF TECHNOLOGIES	3-1
3.2.1 Monitoring	3-2
3.2.2 Institutional Controls	3-2
3.2.3 In-place Containment	3-2
3.2.4 Source Collection	3-6
3.2.5 Treatment	3-6
3.2.6 Temporary Storage/Disposal	3-12
3.2.7 Dewatering and Water Treatment	3-13
3.3 SUMMARY OF RETAINED TECHNOLOGIES	3-21

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

4.0	DEVELOPMENT AND EVALUATION OF ALTERNATIVES	4-1
4.1	INTERIM ACTION ALTERNATIVES	4-1
4.1.1	Alternative 1 - No Action	4-2
4.1.2	Alternative 2 - Monitoring	4-2
4.1.3	Alternative 3 - Institutional Controls	4-3
4.1.4	Alternative 4 - Slurry Wall with Cap	4-3
4.1.5	Alternative 5 - Multilayered Cap	4-4
4.1.6	Alternative 6 - In-situ Vitrification	4-4
4.1.7	Alternative 7 - Chemical Fixation with Onsite Storage	4-6
4.1.8	Alternative 8 - Chemical Fixation with Offsite Disposal	4-9
4.2	INTERIM ACTION EVALUATION CRITERIA	4-10
4.2.1	Overall Protection of Human Health and the Environment	4-10
4.2.2	Conformance with ARARs	4-10
4.2.3	Reduction of Mobility, Toxicity, or Volume	4-10
4.2.4	Short- and Long-term Effectiveness	4-11
4.2.5	Implementability	4-12
5.0	ECONOMIC EVALUATION OF ALTERNATIVES	5-1
5.1	ECONOMIC ASSUMPTIONS	5-1
5.2	ALTERNATIVE COSTING	5-3
5.2.1	Alternative 1 - No Action	5-3
5.2.2	Alternative 2 - Monitoring	5-3
5.2.3	Alternative 3 - Institutional Controls	5-4
5.2.4	Alternative 4 - Slurry Wall with Cap	5-4
5.2.5	Alternative 5 - Multilayered Cap	5-5
5.2.6	Alternative 6 - In-situ Vitrification	5-5
5.2.7	Alternative 7 - Chemical Fixation with Onsite Storage	5-6
5.2.8	Alternative 8 - Chemical Fixation with Offsite Disposal	5-7
5.3	SENSITIVITY ANALYSIS	5-8
6.0	CONCLUSIONS	6-1
6.1	ALTERNATIVE SCREENING	6-1
6.2	ALTERNATIVE EVALUATION	6-4
6.2.1	Alternative 4 - Slurry Wall with Cap	6-5
6.2.2	Alternative 5 - Multilayered Cap	6-5
6.2.3	Alternative 6 - In-situ Vitrification	6-6
6.2.4	Alternative 7 - Chemical Fixation with Onsite Storage	6-6
6.2.5	Alternative 8 - Chemical Fixation with Offsite Disposal	6-7
6.3	CONCLUSIONS	6-7
7.0	REFERENCES	7-1
	APPENDIX A - Comments and Responses	A-1

<u>LIST OF TABLES</u>	<u>Page</u>
2-1 SUMMARY OF CONTAMINANTS IN SOIL AND SLUDGE	2-10
2-2 SUMMARY OF CONTAMINANTS IN GROUNDWATER	2-11
2-3 M-1 SETTLING BASINS EVALUATION BASIS	2-18
3-1 IDENTIFICATION OF POTENTIAL TECHNOLOGIES FOR SOILS AND SLUDGES	3-22
3-2 IDENTIFICATION OF POTENTIAL TECHNOLOGIES FOR WATER	3-28
3-3 TECHNOLOGY SCREENING FOR SOILS AND SLUDGES	3-32
3-4 TECHNOLOGY SCREENING FOR WATER	3-36
4-1 TECHNICAL EVALUATION OF ALTERNATIVES - THRESHOLD CRITERIA	4-14
4-2 TECHNICAL EVALUATION OF ALTERNATIVES - EVALUATION CRITERIA	4-16
5-1 PRESENT WORTH SUMMARY TABLE	5-9
5-2 ALTERNATIVE 2 - GROUNDWATER AND AIR MONITORING - COST ESTIMATE	5-10
5-3 ALTERNATIVE 3 - INSTITUTIONAL CONTROLS - COST ESTIMATE	5-11
5-4 ALTERNATIVE 4 - SLURRY WALL WITH CAP - COST ESTIMATE	5-12
5-5 ALTERNATIVE 5 - MULTILAYERED CAP - COST ESTIMATE	5-13
5-6 ALTERNATIVE 6 - IN-SITU VITRIFICATION - COST ESTIMATE	5-14
5-7 ALTERNATIVE 7 - CHEMICAL FIXATION WITH ONSITE STORAGE - COST ESTIMATE	5-15
5-8 ALTERNATIVE 8 - CHEMICAL FIXATION WITH OFFSITE DISPOSAL - COST ESTIMATE	5-17
5-9 SENSITIVITY ANALYSIS	5-18
6-1 ALTERNATIVE CLASSIFICATION	6-3
6-2 REDUCTION OF MOBILITY, TOXICITY, OR VOLUME EVALUATION	6-9
6-3 SHORT-TERM EFFECTIVENESS EVALUATION: COMMUNITY PROTECTION	6-11
6-4 SHORT-TERM EFFECTIVENESS EVALUATION: WORKER PROTECTION	6-12
6-5 LONG-TERM EFFECTIVENESS EVALUATION	6-13

LIST OF TABLES (Continued)

	<u>Page</u>
6-6 IMPLEMENTABILITY EVALUATION	6-15
6-7 COST EVALUATION	6-17

LIST OF FIGURES

1-1 M-1 SETTLING BASINS AND LIME SETTLING BASINS AREA MAP	1-2
1-2 DECISION FLOW CHART FOR INTERIM ACTION VERSUS MONITORING/MAINTENANCE ON HOT SPOT IRAs	1-4
2-1 M-1 SETTLING BASINS FIELD INVESTIGATION	2-8
6-1 IRA ALTERNATIVE RANKING	6-2

1.1 PURPOSE OF THE INTERIM RESPONSE ACTION (IRA) ALTERNATIVE ASSESSMENT DOCUMENT

The IRA Alternative Assessment Document describes the process and results of the alternative assessment conducted for the M-1 Settling Basins at the Rocky Mountain Arsenal (RMA). The M-1 Settling Basins are located in the South Plants area of RMA near December 7th Avenue, just east of D Street (Figure 1-1). The M-1 Settling Basins are evaluated as being a direct source of arsenic contamination to the groundwater. This evaluation is discussed in subsection 2.2.2.

Technologies and alternatives have been developed that will remove or contain the apparent source of groundwater contamination at this site. These alternatives will be evaluated to assess whether there is a clear and significant benefit in performing an interim response action now. The selection of the preferred interim action is presented in Section 6.0.

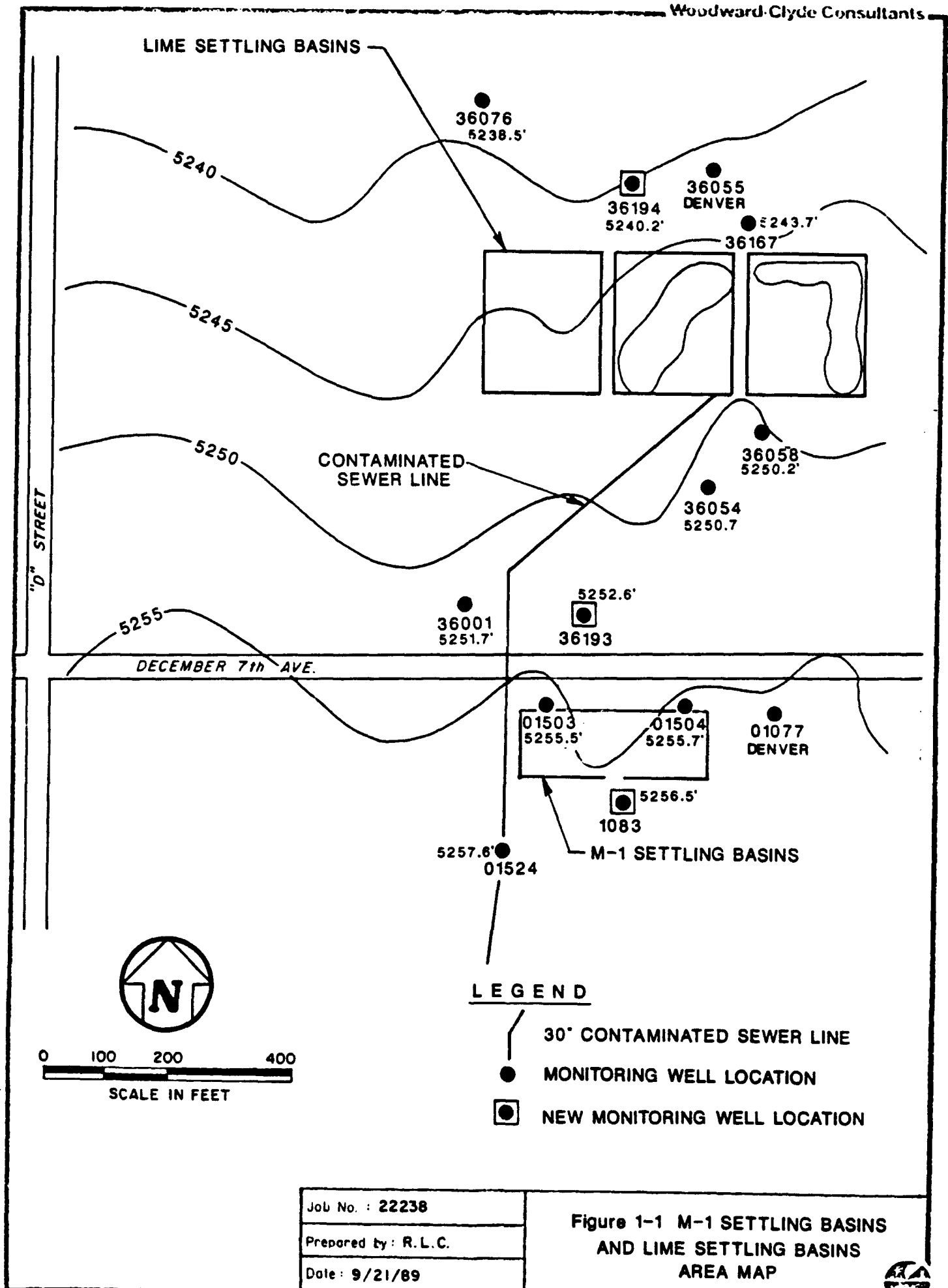
The interim response action referenced herein is identified in Section XXII of the Federal Facility Agreement, paragraph 22.1 (I) and is governed by the process set forth in paragraphs 22.5 - 22.14 of that Agreement.

The goal of this assessment document is to evaluate alternatives based upon, but not limited to, factors such as the protection of human health and the environment, mitigation of the threat of human health and the reasonableness of cost and timeliness. Consistent with the Comprehensive Environmental Response, Compensation and Recovery Act of 1980 (CERCLA), as amended by SARA, 1986, and the National Contingency Plan (NCP), the assessment seeks to balance preferences for treatment on site and for responses that permanently reduce the mobility, toxicity, or volume of hazardous substances against the need, in the context of removal actions, for consistency with the final remedy and for responses that are practical, cost-efficient, and that reduce or control hazards posed by the site as early as possible.

1.2 IRA CANDIDATE SELECTION CRITERIA

To evaluate whether and what type of response action is necessary and appropriate, the following questions have been developed as part of a decision logic:

- (1) Is the site an active primary source?
 - Is it an active source of groundwater contamination?
 - Is it a primary groundwater contamination source?



- (2) Does the site pose a significant risk to human or biota receptors?
 - Have potential receptors been identified?
 - Have previous studies been confirmed by new data?
 - Is there any conflicting evidence?
- (3) Is there a significant long-term benefit if an IRA is done now?
 - Will interim action result in an accelerated cleanup?
 - Will interim action reduce long-term costs?

The type of action taken and the timing of the action will depend on the responses to the above questions. The decision logic is shown in Figure 1-2.

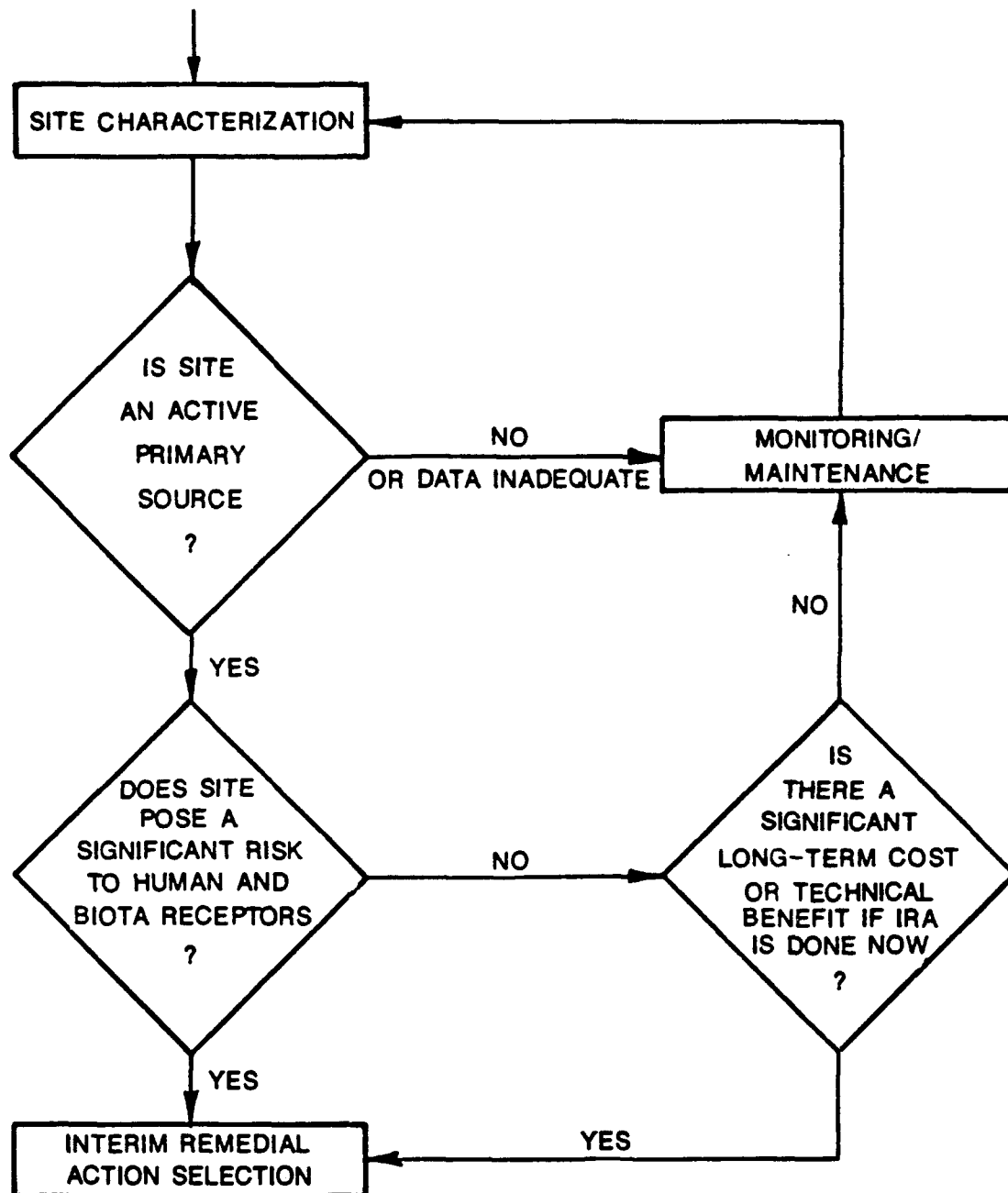
If the answers to the questions on the decision flow chart are inconclusive then reasonable yet conservative assumptions favoring a protective response will be adopted.

The M-1 Settling Basins have been evaluated as being an active primary source of groundwater contamination. Although this site does not appear to pose a significant risk to human or biota receptors at this time, there appears to be both a long-term cost and technical benefit in performing an IRA now since treatment after the arsenic has spread becomes both more costly and complex insofar as a larger area must be addressed. Alternative interim response actions are discussed in this document. The benefit in performing any of these actions is discussed in Section 6.0.

1.3 REPORT ORGANIZATION

This Alternative Assessment Document is divided into five additional text sections and a reference section.

Section 2.0 of this Alternative Assessment Document summarizes the information and results of the current and previous investigations, including a brief description of the site, extent of contamination, and a summary of the evaluation basis. Section 3.0 identifies and provides a preliminary evaluation of feasible interim action technologies. Section 4.0 presents the alternatives developed from the feasible technologies, provides a detailed description of each site-specific alternative, and describes the criteria used to evaluate the alternatives. Section 5.0 presents a cost estimate of each alternative. Section 6.0 presents an evaluation of the alternatives.



Job No : 22238

Prepared by: D.C.C.

Date: 6/15/89

Figure 1-2 - DECISION FLOW CHART FOR
INTERIM ACTION VERSUS
MONITORING/MAINTENANCE
ON HOT SPOT IRAs



2.0
SITE BACKGROUND AND INTERIM ACTION INVESTIGATION

2.1 SITE DESCRIPTION

2.1.1 Location

The M-1 Settling Basins are located in the South Plants area just south of December 7th Avenue along the northern edge of the northwest quarter of Section 1 at the Rocky Mountain Arsenal (RMA). The northwest corner of the basins is 75 feet south of the centerline of December 7th Avenue and 25 feet east of the contaminated sewer line that extended from the South Plants to the Lime Settling Basins (Figure 1-1). The elevation of the ground surface in the M-1 Settling Basins area is approximately 5,265 feet above mean sea level (MSL). The basins and the berms surrounding them, all of which are now buried and partially built upon, occupy an area of approximately 46,200 square feet.

2.1.2 History

Two basins were originally constructed in 1942, but when these filled with solids, a third was constructed in 1943. All three were unlined, each measured approximately 90 feet wide (E-W), 115 feet long, and 7 feet deep, according to the as-built drawings. They were initially constructed to treat waste fluids from the lewisite facility. However, lesser amounts of waste materials from alleged spills within the acetylene generation building, the thionylchloride plant, and the arsenic trichloride plant may have been routed through floor drains and the connecting piping to the basins (Ebasco Services, Inc. 1987).

The liquids discharged into the basins first passed through a set of reactor towers where calcium carbonate was added, then through a wooden trough into the M-1 Settling Basins where the arsenic precipitated out of solution. The elutriate was decanted off through an 18-inch-diameter pipe to the Lime Settling Basins in Section 36 where final treatment occurred and then routed into Basin A (Ebasco Services, Inc. 1987).

The basins also received a considerable amount of mercuric chloride catalyst, possibly from a spill. Various sources reported quantities such as 183,000 pounds, 500 pounds, 30,000 gallons, and \$25,000 worth (Ebasco Services, Inc. 1988).

The basins were backfilled, probably in 1947, and are now covered with soil and some structures. The facilities that surround the M-1 Basins area were used in the manufacture of bicycloheptadiene until 1974.

2.1.3 Geology

This section describes the regional geologic setting at RMA and the site-specific geology at the M-1 Settling Basins.

2.1.3.1 Regional Geology

The RMA is located about 7 miles northeast of central Denver in western Adams County. It occupies approximately 27 square miles within the Colorado Piedmont section of the Great Plains physiographic province. The surficial deposits of this area are characterized primarily by a veneer of wind-deposited and alluvial materials. Most of the topography at the Arsenal is gently rolling; however, there are several prominent hills that contain outcrops of resistant bedrock (Costa 1982).

The geologic history of the RMA and surrounding area spans at least 1-3/4 billion years and is recorded by the rock units that underlie the RMA. The oldest rocks are Precambrian crystalline units that occur approximately 12,000 feet below the surface. The youngest units are the Quaternary age surficial deposits that blanket the RMA. Since the Precambrian, the area has experienced several advances and withdrawals of shallow marine seaways, three episodes of orogeny (mountain building), and three periods of relative crustal stability that preceded the orogenic episodes. The first orogenic episode began in the Pennsylvanian period, the second in the Cretaceous, and the third, the Laramide Orogeny, occurred during the late Cretaceous and early Tertiary periods. The Laramide Orogeny was responsible for uplifting the Front Range Mountains and down-warpage the Denver Basin.

Following the Laramide Orogeny, relative crustal stability existed in the Eocene Epoch. Periods of extensive erosion and deposition in late Eocene were followed by extensive volcanic eruptions during the Oligocene. Then, during the Pleistocene, a cooler, wetter climate brought periods of glaciation to the mountains (Hansen 1982). Regional uplift, mountain glaciation, stream erosion, and subsequent deposition were responsible for the Quaternary deposits and shaping the present-day topography (Haun 1965).

The Rocky Mountain Arsenal lies within the Denver Basin, one of the largest structural basins in the Rocky Mountain region. It covers approximately 60,000 square miles in portions of Colorado, Nebraska, Wyoming, and Kansas. The Denver Basin is an asymmetrical north-south trending syncline with its structural axis close to and parallel to the Front Range. Rock units on the west flank of the basin dip gently to the east though the dip becomes progressively steeper near the boundary between the Front Range uplift and the Denver Basin (Hansen 1982). The east flank of the basin generally dips to the west at one degree or less (Sonneberg 1982).

The Denver Basin is filled with approximately 15,000 feet of sediments. Several major transgressions followed by periods of emergence resulted in the deposition of both marine and continental sediments (Haun 1965) consisting of conglomerate, sandstone, siltstone, shale, limestone, dolomite, coal, lignite, and volcanoclastic sediments. The Laramide Orogeny marked the last retreat of the marine seaway and, thus, sediments from the upper Cretaceous and the lower Tertiary record the final regression of the inland sea (Weimer 1973).

2.1.3.2 Stratigraphy

The full stratigraphic section at the Arsenal was penetrated by a deep injection well drilled in Section 26 in 1961. The well, used for contaminated wastewater disposal, reached a total depth of 12,045 feet in Precambrian basement rock. Injection of wastewater continued from March 1962 until September 1965. The operation was abandoned in 1965 after the injection of wastewater was correlated to an abundance of earthquakes in the area (Evans 1966).

Lithologic information obtained from the well indicates that there are 11,950 feet of Cambrian to Tertiary sedimentary rocks beneath the Rocky Mountain Arsenal. Unconsolidated Quaternary deposits unconformably overlie the bedrock formations. Within these sediments are several aquifers including the Fox Hills sandstone of late Cretaceous age, the Laramie and Arapahoe Formations of late Cretaceous age, portions of the Denver Formation of late Cretaceous and early Tertiary age, and the overlying Quaternary surficial deposits (May 1982). The units of greatest concern at the RMA include portions of the Denver Formation and the unconsolidated Quaternary surficial deposits.

2.1.3.3 Denver Formation

The Denver Formation, which subcrops and occasionally outcrops at the Rocky Mountain Arsenal, was originally as much as 900 feet thick, but due to subsequent erosion, it now ranges from 250 to 500 feet at the Arsenal (May 1982). It was derived predominately from the erosion of andesitic and basaltic rocks and was deposited in fluvial environments, and as lacustrine deposits on an extensive piedmont plain (Romero 1976).

Materials in the Denver Formation include olive-gray, brown, and green-gray interbedded claystone, siltstone, sandstone, conglomerate, carbonaceous clay shale, low-grade coal, and lignite. Volcanoclastic material is also present in the Denver Formation and consists of angular to subangular lithic fragments and minerals in a fine-grained clay matrix. The clay matrix is bentonitic and is probably the weathering product of volcanic ash (May 1982).

Individual aquifers within the Denver Formation range in thickness from several inches up to 60 feet. They are generally discontinuous, lenticular, and consist of poorly cemented, medium- to fine-grained sandstone, which grade vertically and laterally into siltstone and clay shale (May 1982).

2.1.3.4 Quaternary Deposits

Unconsolidated sediments of Quaternary age unconformably overlie the Denver Formation at the Arsenal. There are, however, a few locations where bedrock is exposed at the surface near topographic highs. The upper surface of the Denver Formation is a paleotopographic or erosional surface that was incised by ancient stream channels. These paleochannels were filled by unconsolidated surficial deposits (Costa 1982). The surficial deposits previously referred to as Quaternary alluvium or the alluvial aquifer are up to 130 feet thick and consist of alluvium, loess, and eolian deposits. They have been subdivided into eight units ranging in age from Pleistocene to Holocene (Scott 1960). At the Rocky Mountain Arsenal, six units have been mapped. They are the Verdos alluvium of Kansan age, Slocum alluvium of Illinoian age, Louviers and Broadway of Wisconsin age, Piney Creek alluvium, and Post-Piney Creek alluvium of Holocene age (DeVoto 1968).

2.1.3.5 Alluvium

The alluvial deposits are generally composed of yellowish-brown to very pale orange clays, silts, sands, gravels, and boulders. Coarser alluvial material is found in the paleochannels (May 1982). The alluvium is generally unconsolidated except where calcium carbonate has cemented sand and gravel into a conglomerate. The grain size of the alluvial material ranges from clay size to boulders. The sands are subangular to subrounded quartz with mica, heavy minerals, and chert. According to the Unified Soil Classification System, they are predominately SM (sand-silt mixtures) and SP (poorly graded sands) and often contain gravel. The sands are lenticular and grade laterally and vertically into clay, silt, and gravel (May 1982).

2.1.3.6 Loess/Eolian Deposits

Loess and other eolian deposits of Pleistocene and Holocene age are widely distributed at the RMA. The loess is generally less than 10 feet thick but may be up to 20 feet thick in the eastern part of the area. It consists of yellowish-brown to light grayish-brown sandy silt and may contain large amounts of clay. The other eolian deposits are generally 10 to 20 feet thick but may be as much as 40 to 50 feet thick. They consist of light-brown fine sand, sandy silt, and clay (Lindvall 1980).

2.1.3.7 Site Geology

The M-1 Settling Basins are located on a paleotopographic high near the headwaters of a series of paleodrainages that originate in the upland area now occupied by Section 1. Two significant stratigraphic units have been identified at the site. These are the Quaternary Alluvium and the Cretaceous-Tertiary Denver Formation.

The surficial materials in the M-1 Settling Basins are 10 to 15 feet thick and unconformably overlie the Denver Formation. The entire area around the basins is covered with a veneer of imported soil. The soil cover over the waste material in the basins ranged from 2 to 4 feet thick.

The unconsolidated alluvial material is composed of yellowish-brown to grayish-brown, fine-grained to medium-grained, subangular, alluvial, eolian, and eluvial sands, silts, and clays, with some minor amounts of gravel.

The Denver Formation, to the depth penetrated, is composed of weathered, dark to dusky brown, hard, dense, blocky claystone interbedded with medium-gray, hard, sandy to gravelly siltstone and lignite. The contact between the alluvial unit and the Denver Formation is generally characterized by a claystone; however, it may also be marked by siltstone or lignite. The elevation of the contact between the alluvial soil and the top of the Denver Formation is variable at RMA. In the M-1 Settling Basins area, the contact was found between an elevation of approximately 5,246 and 5,254 feet above MSL (Ebasco Services, Inc. 1989a).

2.1.4 Hydrology

This section describes the regional hydrologic setting at RMA and the site-specific hydrology at the M-1 Settling Basins.

2.1.4.1 Regional Hydrology

The Rocky Mountain Arsenal lies within the South Platte River drainage basin. The river is located several miles to the west and northwest of the Arsenal.

Several tributary drainages flow northwest across the Arsenal to the South Platte River. Groundwater at the Arsenal occurs in the Quaternary surficial deposits and in several bedrock aquifers. The aquifers of primary concern at the Rocky Mountain Arsenal, however, are the Quaternary deposits and portions of the underlying Denver Formation. The deeper bedrock aquifers are apparently separated from the

Denver Formation by 50 to 100 feet of shale called a "buffer zone," which acts as an aquitard (Romero 1976).

Groundwater at the Rocky Mountain Arsenal generally flows from the southeast to the northwest and eventually discharges into the South Platte River. There are local variations in flow direction (May 1982). One such variation is caused by the local bedrock paleotopography and the groundwater mound that exists beneath the South Plants area in Section 1 (May 1982). Groundwater in the unconsolidated Quaternary alluvial aquifer is found under unconfined conditions. Groundwater in the Denver Formation is found under unconfined and confined flow conditions at the Arsenal. The nature of the contact between the alluvial aquifer and the Denver Formation may determine whether the flow conditions in the Denver Formation are unconfined or confined. If Denver Formation sandstones subcrop below the saturated alluvium, the base of the subcropping sandstone is considered the base of the unconfined system.

The hydraulic conductivity of the two aquifers varies considerably. The hydraulic conductivity of the alluvium has been measured at between 9.08×10^{-1} to 2.4×10^{-3} cm/sec. The lower hydraulic conductivity values were found in the Basin A area. Hydraulic conductivity measured in the Denver Formation yielded values ranging from 10^{-7} cm/sec for clay shales to 10^{-3} cm/sec to 10^{-4} cm/sec for sandstones (May 1982).

Due to the contrast in hydraulic conductivity between the Denver Formation clay shales and the alluvium, groundwater flow and contaminant transport through unfractured bedrock is assumed to be relatively slow compared to flow and transport in either saturated alluvium or in fractures or sandstones in the Denver Formation (Stollar 1988). Within the alluvial unit, the paleochannels generally have higher hydraulic conductivities than the surrounding alluvial materials due to the coarser materials in the paleochannels. These channels appear to serve as conduits that move alluvial groundwater at higher rates and volumes than in other parts of the unconfined system (May 1982). The primary groundwater flow components at the Arsenal generally follow the paleochannels in the alluvium; however, flow is not restricted to only the paleochannels. Groundwater flow does occur over channel divides and through the Denver Formation (May 1982).

2.1.4.2. Site Hydrology

Both the alluvial and bedrock units are known to be water-bearing units in the M-1 Settling Basins area. Previous investigations conducted at RMA have concluded that the alluvial aquifer is unconfined and that the Denver Formation may be partially confined in some zones beyond the upper weathered zone (Ebasco Services, Inc. 1989b). The weathered portion of the Denver Formation is apparently in contact

with the alluvial aquifer. Since this investigation focused primarily on evaluating impacts to the alluvial aquifer, the discussion will be limited to the characteristics of the unconfined alluvial aquifer.

In the M-1 Settling Basins area, groundwater flow in the alluvial aquifer is apparently toward the north and possibly slightly northwest due to the influence of localized mounding of groundwater in the South Plants area. The local groundwater gradient is in the range of 0.008 to 0.011 ft/ft. Due to seasonal variations and local topography, the top of the groundwater ranges from approximately 5 to 10 feet below ground surface. The average saturated thickness of the alluvial aquifer is approximately 8 feet.

Aquifer tests conducted on the alluvial aquifer during previous investigations at RMA indicate that the hydraulic conductivity of the unit is in the 6.0×10^{-3} cm/sec to 2.4×10^{-3} cm/sec range. By comparison, the reported hydraulic conductivity value for the Denver Formation is in the range of 5×10^{-5} cm/sec.

2.1.5 Previous Investigations

2.1.5.1 Soils

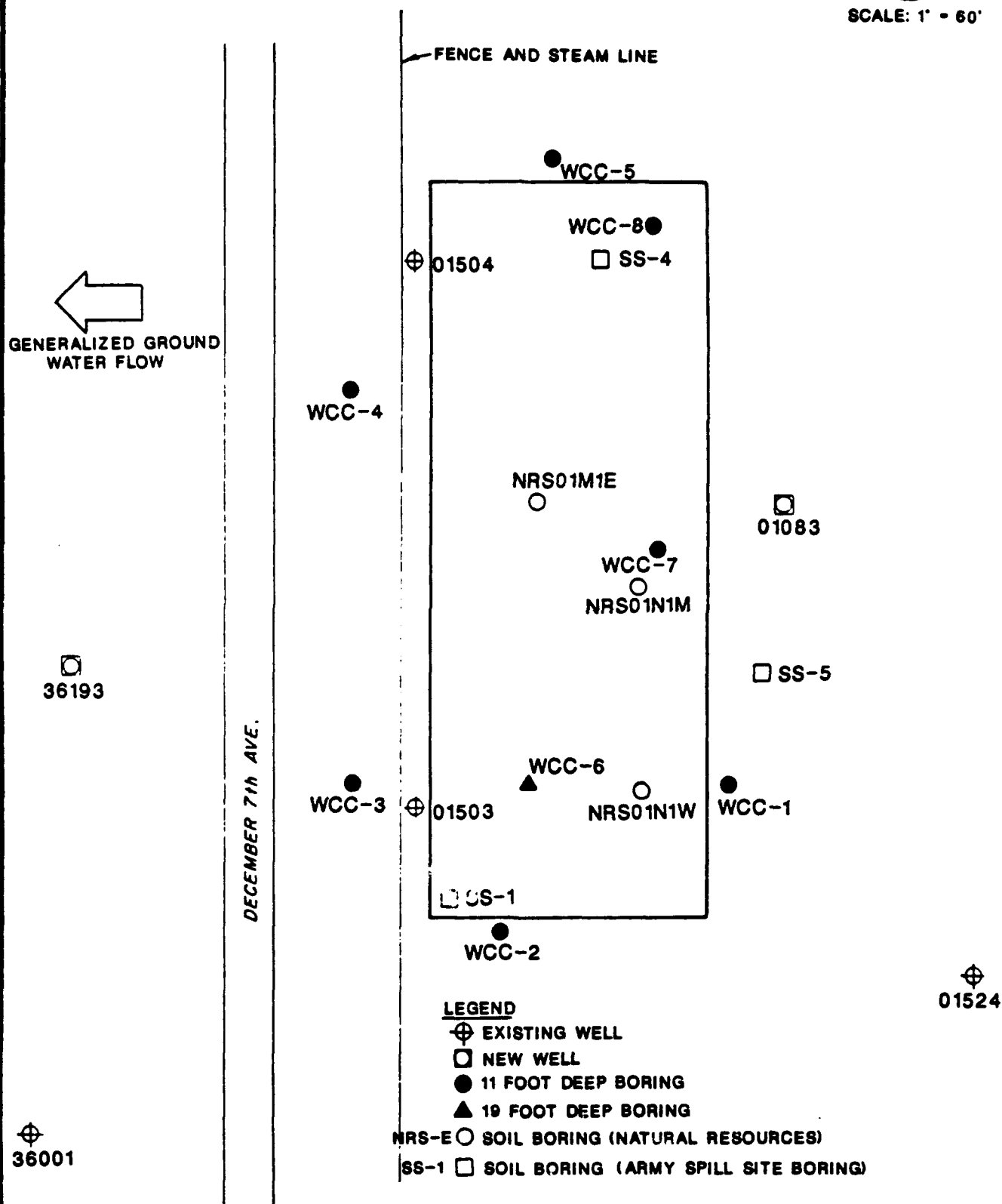
The M-1 Settling Basins were investigated by the Army's consultant, Ebasco, in 1987 and by Shell's consultant, Morrison-Knudsen Engineers in 1988. Twenty-six soil and waste samples were taken from 6 borings within or near the M-1 Settling Basins during the two investigations. The locations of these borings are shown in Figure 2-1. The samples were analyzed for volatiles, semivolatiles, ICP metals, arsenic, mercury, and thiodiglycol.

2.1.5.2 Groundwater

Several groundwater monitoring wells have been installed to monitor alluvial groundwater in the vicinity of the M-1 Settling Basins. Well Nos. 01503 and 01504 are located in the berm immediately downgradient of the M-1 Basins, Well No. 01524 is located approximately 100 feet upgradient of the western-most basin, Well No. 36001 is located approximately 200 feet northwest (downgradient) of the western-most basin, and Well No. 01077 is located approximately 100 feet east of the basin area. The locations of these wells are shown in Figure 2-1. Samples from the wells were analyzed for total and dissolved arsenic, mercury, volatiles, semivolatiles, and pesticides during previous investigations. In spring 1989, Well Nos. 01503, 01504, 01524, 01077, 36001, and new Well Nos. 01083 and 36193 were sampled and analyzed for total and dissolved arsenic and mercury.



SCALE: 1" = 60'



Job No. : 22238

Prepared by: R.L.C.

Date: 10/19/89

Figure 2-1 M-1 SETTLING BASINS
FIELD INVESTIGATIONS

2.2 NATURE AND EXTENT OF CONTAMINATION

2.2.1 Soils

Soil samples collected and analyzed during investigations of the M-1 Settling Basins indicated high concentrations of arsenic and mercury in the soil in and around the basins at depths of 0.5 foot to approximately 7.0 feet. The concentration of arsenic and mercury in samples taken within the basins was variable and ranged from 0.01 to 11.0 percent. Concentrations of these constituents are reduced at depths below approximately 7 feet and in the soil surrounding the basins. Table 2-1 shows a summary of the contaminants found in soil samples taken during the previous studies.

2.2.2 Groundwater

Groundwater samples taken and analyzed during previous investigations showed a difference in the concentration of arsenic between filtered and unfiltered groundwater samples from wells immediately downgradient of the basins. Unfiltered groundwater samples from Well Nos. 01503 and 01504 indicated up to 59,000 ug/l arsenic, while the filtered samples indicated less than 0.01 ug/l for each well. The explanation for this difference is unclear. It has been suggested that a high concentration of arsenic is attached to soil particles moving with the groundwater as it leaves the M-1 Settling Basins area.

Analytical results from groundwater sampling conducted in spring 1989 confirm that there are high levels of arsenic in the groundwater, but these results show little difference between filtered and unfiltered samples (WCC 1989). Total and dissolved arsenic concentrations are quite similar in magnitude and indicate a high concentration of arsenic immediately downgradient of the M-1 Settling Basins. One possible explanation for the difference between the filtered/unfiltered samples in previous investigations versus the similarity in filtered/unfiltered samples in the 1989 investigation is that different sample preservation methods may have been used. In either case, the high concentrations of arsenic downgradient of the M-1 Settling Basins clearly indicate that this site is a direct source of arsenic contamination to the groundwater. Table 2-2 is a summary of the contaminants found in groundwater from wells in the M-1 Settling Basins area.

TABLE 2-1
SUMMARY OF CONTAMINANTS IN SOIL AND SLUDGE

Contaminant	SOIL		SLUDGE	
	No. of Indications	Range (ug/g)	No. of Indications	Range (ug/g)
Volatile Organic Compounds/GCMS				
Methylene Chloride (CH ₂ CL ₂)	3	3.42-6.70	4	3.0-6.1
Bicycloheptadiene (BCHPD)	6	1.8 -5000	5	0.51-600
Semivolatile Organic Compounds/GCMS				
Aldrin (ALDRN)	2	2.0-30	6	1.4-60
Dicyclopentadiene (DCPD)	6	60-4000		
Dieldrin (DLDRN)	5	0.4-100		
Hexachlorocyclopentadiene (CL6CP)	1	3000		
Isodrin (ISODR)	1	10		
Metals/ICP				
Cadmium (Cd)	7	1.3-31.0	9	7.86-3900
Chromium (Cr)	14	9.86-23	2	7.4-8.42
Copper (Cu)	14	7.2-21	2	9.0-21.8
Lead (Pb)	12	13-64	11	16.4-248
Zinc (Zn)	7	39-76	7	16.1-70.7
Separate Analyses				
Arsenic (As)	14	9.2-1300	12	17,000-110,000
Mercury (Hg)	11	0.33-210	12	400-9,400

Sources:

RMA Data Base, August 1989
Ebasco Services, Inc. 1988
Woodward-Clyde Consultants 1989

TABLE 2-2
SUMMARY OF CONTAMINANTS IN GROUNDWATER

	No. of Indications	Upgradient (Well Nos. 01083 01524, 01077) Range (ug/l)	No. of Indications	Downgradient (Well Nos. 01503, 01504, 36001, 36193) Range (ug/l)
Volatile Organic Compounds/GCMS				
Benzene (C6H6)	4	406-3,400	9	22-32,500
Bicycloheptadiene (BCHPD)	3	13.2-74.0	4	2,379-9,500
Carbon Tetrachloride (CCL4)	2	62.0-74.0	1	230.0
Chlorobenzene (CLC6H5)	2	1,073-35,000	6	25-40,500
Chloroform (CHCL3)	3	6.0-250	9	30.0-425,000
Dibromochloropropane (DBCP)	2	4.5-7.74	--	---
Methylisobutyl Ketone (MIBK)	3	10.0-7,200	5	6.9-3,063
Xylene (XYLEN)	1	12.0	2	7.0-1,150
Tetrachloroethene (TCLEE)	4	317.0-1,100.0	4	3.0-630.0
Toluene (MEC6H5)	4	320.0-1,200	7	1.7-2,600
Dichloroethene (12DCLE)	1	690.0	1	2,300
Trichloroethene (TRCLE)	3	331.0-1,500	6	1.9-2,250
Dichlorobenzene (DCLB)	--	---	3	5.6-5,500
Methylene Chloride (CH2CL2)	--	---	2	380-1,250
Semivolatile Organic Compounds/GCMS				
Aldrin (ALDRN)	3	0.29-3.1	2	0.75-1.58
Chlorophenylmethyl Sulfide (CPMS)	2	89.0 -140.0	5	13.4 -> 300
Chlorophenylmethyl Sulfoxide (CPMSO)	1	17.0	4	21.5 -> 300
Chlorophenylmethyl Sulfone (CPMSO2)	3	20.9-28.2	7	20.1-160
Dibromochloropropane (DBCP)	2	4.5-7.74	4	76 -> 300
Dicyclopentadiene (DCPD)	1	330.0	15	97-84,200
Dieldrin (DLDRN)	2	0.325-0.355	3	1.26-820.0
Diisopropyl methyl Phosphonate (DIMP)	1	33.5	9	3.0-6,600
Dimethylmethyl Phosphonate (DMMP)	2	12.6-45	1	130
Dithiane (DITH)	1	1.96	1	8.6
Endrin (ENDRN)	2	1.40-5.9	2	0.71-1.53
Hexachlorocyclopentadiene (HCPD)	--	---	---	----
Isodrin (ISODR)	1	0.252	2	2.0
Atrazine (ATZ)	--	---	1	190
Phenol (PHENOL)	--	---	3	7.6-28

TABLE 2-2 (Continued)

	No. of Indications	Upgradient (Well Nos. 01083, 01524, 01077) Range (ug/l)	No. of Indications	Downgradient (Well Nos. 01503, 01504, 36001, 36193) Range (ug/l)
Organochlorine Pesticides (GCEC)				
Dichloroethane (PPDDE)	1	0.86	2	0.317-.551
Trichloroethane (PPDDT)	2	0.790-1.5	3	0.454-
Organochlorine Pesticides (GCEC) (Cont)				
Aldrin (ALDRIN)			5	0.167-9.09
Hexachlorocyclopentadiene (CLGCP)			5	0.721-38.6
Endrin (ENDRN)			4	0.264-3.95
Isodrin (ISODR)			4	0.223-2.3
Chlordane (CLDAN)			3	2.62-19.7
Dieldrin (DLDRN)			2	0.0774-2.77
Organosulfur Compounds/GCFID				
Dimethyldisulfide (DMDS)	2	3.16-140		
Chlorophenylmethyl Sulfide (CPMS)			3	> 50-990
Chlorophenylmethyl Sulfoxide (CPMSO)			3	32-36.6
Chlorophenylmethyl Sulfone (CPMSO2)			3	> 100-1,080
Benzothiazole (BTZ)			2	19.4-22.2
Dithane (DITH)			2	1.56-1.67
1,4-Oxathiane (OXAT)			1	3.34
Metals/ICP				
Copper (Cu)	1	44.8		
Zinc (Zn)	1	24.2		
DIMP/DMMP				
Diisopropylmethyl Phosphonate (DIMP)			2	58.8-72.9
Dimethylmethyl Phosphonate (DMMP)			5	1.39-1,100
Arsenic				
Previous Investigations				
Total			2	23,400-59,300
Filtered			2	0.0058-0.0063
1989				
Total	2	7.15-10.30	7	18.6-19,700
Filtered	2	3.01-6.36	7	2.57-12,900

TABLE 2-2 (Continued)

	No. of Indications	Upgradient (Well Nos. 01083, 01524, 01077) Range (ug/l)	No. of Indications	Downgradient (Well Nos. 01503, 01504, 36001, 36193) Range (ug/l)
Mercury				
Previous Investigations	1	0.164	---	----
1989				
Total	1	0.132	6	1.93-16,600
Filtered	--	---	6	2.45-16,600

Sources:

RMA Data Base, August 1989
WCC 1989

2.3 CONTAMINANT FATE AND TRANSPORT

The contaminants observed in the field investigation can exist in several chemical forms in the environment and can progress through several media in a number of different ways. This section presents the fate and transport of both the predominant organics and metals detected in the soils and sludges during these field investigations. First, the fate and transport of the predominant organic compounds will be discussed. This will be followed by a discussion of the fate and transport of metals detected at the M-1 Settling Basins.

2.3.1 Organics Fate and Transport

Although the sludge material and the overburden soil at the M-1 Settling Basins contain several organic compounds in trace amounts, two organic compounds are present in concentrations as high as four orders of magnitude above their detection limits: bicycloheptadiene and dicyclopentadiene. These compounds will be the focus of this section. Based on the chemical and physical properties of these compounds and on previous fate and transport studies (Ebasco Services, Inc. 1987), several observations can be made:

- Since previous investigations only detected these compounds at depths greater than 4 feet, the volatilization of these compounds is probably negligible.
- Neither compound shows appreciable bioconcentration. This, in addition to the fact that only minimal plant life exists at the site, makes plant uptake and subsequent bioconcentration a minor fate mechanism.
- Microbial degradation of these compounds has been reported to occur. However, given the high arsenic concentrations of the sludge, microbial activity in the sludge material will be minor. If other transport mechanisms remove the compounds from this high arsenic concentration environment into an area that is sustaining microbial activity, some subsequent degradation of these compounds will occur.
- Both compounds will be sorbed on to the sludge material and on to the local sands and silty sands. However, both compounds are susceptible to subsequent desorption and transport with the alluvial groundwater. This mechanism is likely during periods of high groundwater levels, when the alluvial groundwater extends into the sludge material. Since two orders of magnitude increase in the concentration of these compounds is observed in groundwater downgradient,

relative to upgradient, of the M-1 Settling Basins (Table 2-2), it appears that some desorption and subsequent transport with the alluvial groundwater is occurring.

In summary, bicycloheptadiene and dicyclopentadiene appear to be sorbed on to the sludge material and on to the local sands and silty sands. During periods of high groundwater, the compounds are desorbed into the alluvial groundwater and are transported downgradient. These compounds will then slowly degrade to more stable compounds as they migrate into areas of increased microbial activity.

2.3.2 Metals Fate and Transport

The primary metal contaminants of concern at the M-1 Settling Basins are arsenic and mercury. The contaminant assessment report also shows occasional, isolated, elevated concentrations of cadmium. Although arsenic and mercury are present throughout the study area and will be the focus of the discussion, cadmium will also be discussed. A review of the major fate area and transport mechanisms of these compounds (Ebasco Services, Inc. 1987) allows for the following observations:

- Arsenic is mobile in the environment and may be present in several chemical forms (e.g., arsenate in oxidizing environments and arsenite in reducing environments).
- Biomethylation would occur for both arsenic and mercury, if conditions for aerobic activity were present (e.g., large numbers of bacteria, large amounts of organic material and nutrients, neutral pH, moisture, etc). Biomethylation would form volatile methylarsenics and organomercury compounds. These compounds would volatilize, if present at the near surface, to undergo subsequent photolysis or washout in the atmosphere. Since conditions at the M-1 Settling Basins are not conducive to significant aerobic activity and since a large fraction of the metals are present at depths greater than "near-surface," biomethylation and subsequent volatilization is probably not an important fate and transport mechanism.
- Mercury is readily sorbed onto soils. It is not readily leached from either organic-rich or mineral-rich soils. There is little plant life at the site; therefore, mercury uptake by plants will be minor. Mercury can be remobilized by microbial conversion to its methyl and dimethyl forms. However, since conditions are poor for microbial activity, this mechanism is probably minor.

- Leaching of arsenic off of soil and sludge particles would be limited by the sorption of arsenic onto clays with high iron and aluminum oxide content. Since the predominant soil types at the site are sands and silty sands, the arsenic could be leached into and transported with the alluvial groundwater, either as an arsenate or arsenite.
- Cadmium is mobile in aquatic environments. It can be removed from aqueous media by complexing with organic material. Its solubility and subsequent mobility in water is a function of, among other factors, its oxidation state and pH.
- Cadmium can be readily concentrated into vegetable plant matter. However, these concentration effects may be confounded by the phytotoxic effects of cadmium. Since plant life in the area is minimal, it is assumed that the bioconcentration through plant material is minor.

Based on the above observations, it appears that most of the metals present in the soils and sludge at the M-1 Settling Basins are sorbed to the local sands and silty sands as well as the sludge material at the site. Arsenic and some cadmium can be leached and transported with the alluvial groundwater. Leaching and subsequent transport of mercury will be limited.

2.4 APPLICABLE SITE STANDARDS

With the available knowledge of the nature and distribution of chemical contaminants at the site, as well as the fate and transport of these chemicals in the environment, a survey of applicable or relevant and appropriate requirements (ARARs) is necessary. These ARARs will identify any site-specific regulatory requirements that might limit the choice of alternatives. Action-specific and chemical-specific ARARs are considered to the extent that any alternative which cannot potentially meet those requirements will not be carried forward. Site-, action-, and chemical-specific ARARs will be finalized and issued together with the decision document to identify those requirements which will guide the design and implementation of the selected alternative.

2.5 EVALUATION BASIS FOR INTERIM RESPONSE ACTIVITY

This section summarizes the engineering constraints considered in the technology and alternative evaluation process.

The total areal extent of the three M-1 Settling Basins is shown to be 115 feet by 300 feet on design drawings. It is assumed that the waste material in the basins is covered by 2 feet of soil overburden and that the waste material extends to a depth of 7 feet below ground surface. The total volume of the sludge is estimated to be approximately 6,400 yd³.

Volume estimates for the sensitivity analysis consider only a maximum-volume case by assuming a 20-foot perimeter boundary of soil to be treated around the M-1 Settling Basins. In addition, for the sensitivity analysis, the depth of contamination was assumed to be 10 feet below ground surface.

Alluvial groundwater is assumed to be present at approximately 8 feet below ground surface, with some seasonal variation. A low permeability or confining layer is assumed to be present about 15 feet below ground surface. All treatment technologies will address the contents of the basins and the overburden only. No aquifer dewatering and subsequent treatment is assumed to be necessary for the purpose of excavation for this interim response action. Any excavation activities will be performed during the dry season in late summer or early fall to reduce the potential for encountering groundwater.

Preliminary analysis of the waste material in the basins indicates that the in-place waste is approximately 47 percent water. The waste is described as a gray-to-white very wet, silty clay-like material, similar to the consistency of toothpaste. Based on investigations, this material is assumed on the average to be about 8 percent arsenic, 0.5 percent mercury with the balance being calcium oxide or calcium carbonate as measured on a dry basis. The wet density of this material is assumed to be 1.35 tons/yd³.

The soil surrounding the basins is gravelly to silty sands, with lesser amounts of clayey sands to silty sand. The in-place density of this soil is assumed to be 1.5 tons/yd³.

A summary of the evaluation basis is shown in Table 2-3.

**TABLE 2-3
M-1 SETTLING BASINS
EVALUATION BASIS**

Site Characteristics

	<u>Units</u>	<u>Estimates</u>	<u>Maximum</u>
Perimeter	ft	830	910
Surface Area	ft ²	34,500	46,200
Depth of Contamination	ft	7	10
Depth of Groundwater	ft	8-9	10
Depth of Confining Layer	ft	18	18
Volume	yd ³		
Sludge		6,400	6,400
Soil		2,600	10,700
Total		9,000	17,100

Sludge Characteristics

Gray-to-white, very wet silty clay like material
Density: 1.35 tons/yd³

Soil Characteristics

Gravelly-to-silty sands, with lesser amounts of clayey sand to silty sand
Density: 1.5 tons/yd³

<u>Contaminant</u>	<u>Soil Geometric Mean (ug/g)</u>	<u>Sludge Geometric Mean (ug/g)</u>
Volatile Organic Compounds/GCMS		
Methylene Chloride (CH ₂ CL ₂)	3.5	3.7
Bicycloheptadiene (BCHPD)	235	45
Semivolatile Organic Compounds/GCMS		
Aldrin (ALDRN)	8	
Dicyclopentadiene (DCPD)	1340	8
Dieldrin (DLDRN)	4	
Hexachlorocyclopentadiene (CL ₆ CP)	3000	
Isodrin (ISODR)	10	
Metals/ICP		
Cadmium (Cd)	3.6	22.9
Chromium (Cr)	11.9	9
Copper (Cu)	12.6	17.7
Lead (Pb)	26.5	42.7
Zinc (Zn)	61	35.1
Separate Analyses/AA		
Arsenic (As)	78	38300
Mercury (Hg)	6	2550

IDENTIFICATION AND EVALUATION OF INTERIM ACTION TECHNOLOGIES

This section presents the interim action objective and identifies potential interim action technologies specific to the M-1 Settling Basins at the Rocky Mountain Arsenal (RMA). As the preliminary step to identifying interim response action (IRA) alternatives, potentially applicable technologies for the IRAs are identified, described, and evaluated in terms of their feasibility and general effectiveness. Acceptable technologies or combinations of technologies are developed into the IRA alternatives presented in Section 4.0.

3.1 INTERIM RESPONSE ACTION OBJECTIVE

The objective of this IRA is to mitigate the threat of releases from the M-1 Settling Basins. Alternatives to meet this objective are developed using technologies discussed in Section 3.2 and evaluated in Sections 4.0 and 6.0. The evaluation is based on, but not limited to, such factors as protection of human health and the environment, mitigation of the threat to human health, and the reasonableness of cost and timeliness, per the Federal Facility Agreement (FFA), paragraph 22.6.

3.2 IDENTIFICATION AND EVALUATION OF TECHNOLOGIES

This section identifies and evaluates IRA technologies applicable to the M-1 Settling Basins. Tables 3-1 and 3-2 (tables are located at the end of this section) list general response actions and technologies typically applied to contaminated soil and associated groundwater, respectively. Each technology is evaluated as being applicable or not applicable, based on the site-specific and contaminant-specific conditions at the M-1 Settling Basins.

The technologies remaining after this initial evaluation are then described in this section. This description focuses on the technical performance, operational reliability, and implementation of each technology. Several technologies are eliminated from further consideration at this point. Tables 3-3 and 3-4 summarize this discussion.

Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), as amended by SARA, 1986, guidance (Environmental Protection Agency 1988) suggests the selection of no more than 10 or 11 alternatives. The alternatives should include a mix of institutional controls, containment, in-situ treatment, and onsite treatment technologies, as well as onsite storage and offsite disposal. This suggested mix of technologies was applied in selecting the alternatives described in Section 4.0.

This section is organized by general response action. Technologies are introduced with respect to their applicability to address a particular general response. These general response actions include monitoring, institutional controls, containment, source collection, treatment, and storage/disposal.

3.2.1 Monitoring

Monitoring of the M-1 Settling Basins would consist of periodic sampling of upgradient and downgradient groundwater monitoring wells. Groundwater would be analyzed for the organic and inorganic compounds that have been detected in the sludge and contaminated soil in the vicinity of the M-1 Settling Basins. The historical data base, augmented by current and future monitoring, would provide an indication of whether the M-1 Settling Basins are a continuing source of groundwater degradation in the time between the implementation of this IRA and the overall site remediation.

Monitoring is a feasible technology at the M-1 Settling Basins.

3.2.2 Institutional Controls

Although not a technology, institutional controls are incorporated into the assessment as a variation of the no action alternative. Institutional controls would be applicable in the case of no-action, onsite storage or landfill, capping-in-place, or other interim alternatives that result in leaving contaminated materials on site that could be compromised by future excavation or construction activities.

Since a fence and guard post are used to secure the arsenal, site access restrictions are in place to some extent. Additional restrictions, such as fencing around the perimeter of the M-1 Settling Basins, would be feasible.

3.2.3 In-place Containment

Six technologies are identified as either source containment or associated with source containment measures:

- Capping
- Dikes and berms
- Slurry walls
- Grout curtain
- Sheet piling

- **Groundwater interception and treatment**

3.2.3.1 Capping

Capping is a process used to cover buried waste materials to prevent their contact with the land surface and surface water. Substantive performance standards for caps must conform with 40 CFR Part 264.310. As described there, a cap consists of a compacted clay layer, a synthetic geomembrane liner, a sand drainage layer, and a surface layer of vegetated topsoil, asphalt, or rock. For short-term implementation, non-conforming caps are sometimes applicable. These consist only of a compacted clay layer beneath a surface layer of either vegetated topsoil, asphalt, concrete, or rock.

Surface caps must be sloped to provide rapid surface drainage away from the contaminated areas. Collection systems may be incorporated into surface caps; however, this is generally not necessary if high concentrations of mobile contaminants are not present. The technology required to implement this alternative is commonly used for in-place closure of contaminated soils or in conjunction with confinement of contaminated groundwater.

Capping is effective in minimizing the leaching of contaminants from the soil profile above the groundwater table. However, waste materials below the water table will still be transported by groundwater migration. Supplementary groundwater control measures are generally required when soil contamination extends below the groundwater table.

Surface-capping technology is relatively economical to implement, is technically feasible and, when used in conjunction with other groundwater measures, can be effective in reducing contaminant leachate production from near-surface soils.

3.2.3.2 Dikes and Berms

Dikes and berms are well-compacted earthen ridges constructed immediately upslope from, or along the perimeter of, a disposal site. These structures are generally designed to provide short-term protection of critical areas by intercepting storm runoff and diverting the flow to natural or man-made drainage ways.

This technology is a cost-effective, technically feasible method of preventing surface runoff from impacting remediation operations at the M-1 Settling Basins.

3.2.3.3 Slurry Walls

A slurry wall is a vertical, low-permeability wall, typically constructed of a soil-bentonite mixture, which is placed in a trench kept open by a slurry (bentonite-water mixture). The trench is typically 2 to 3 feet wide and is usually keyed into a low-permeability basal unit. A surface capping system is generally constructed in conjunction with the slurry wall.

At this site, low permeability strata of the Denver Formation, which could effectively impede downward migration of contamination, occur at a relatively shallow depth. These conditions are favorable for economical soil-bentonite slurry wall construction. Excavation to the depth for the desired key into the Denver Formation could be accomplished in a single stage by using a backhoe or similar excavation equipment. Slurry wall construction has been performed successfully on other projects under similar conditions and is an accepted method for groundwater or soil contamination containment.

The technology required for slurry wall construction is commonly used in containment of hazardous waste sites. Because of the shallow depth to a low-permeability stratum and generally favorable soil conditions, this technology is feasible for the M-1 Settling Basins. It is relatively economical to implement and may be used in conjunction with a surface capping system or other groundwater control measures as an effective measure of reducing contaminant migration.

3.2.3.4 Grout Curtain

Grout curtains are subsurface barriers created in unconsolidated materials by pressure injection. Grout curtains are generally more expensive than slurry walls, and their ability to develop a continuous low-permeability barrier is questionable. It has been shown that occasionally, as a result of grout shrinkage and erratic movement of the grout through the soil pores, large voids may remain. Sandy soils present at the site could require large volumes of grout, making this alternative potentially very expensive with less control of barrier wall continuity compared to a soil-bentonite slurry wall. For these reasons, this technology is eliminated from further consideration.

3.2.3.5 Sheet Piling

Sheet piling cut-off walls may serve as a groundwater barrier to redirect groundwater flow. Such cut-off walls may be used to redirect or contain groundwater to eliminate contact with contaminated materials and/or to prevent contaminated groundwater and waste material from migrating off site. Of the three available materials for sheet pilings (wood, precast concrete, and steel), steel is the most efficient and cost-effective groundwater barrier.

The installation of a steel sheet piling cut-off wall requires that the pilings be assembled at their edge interlocks before being driven into the ground. The piles are then driven a few feet at a time over the entire length of the wall, using either a pneumatic or steam pile driver, until the appropriate depth is obtained.

Initially, steel sheet piling cut-off walls are quite permeable; the edge interlocks must be loose to facilitate the driving process and to allow water to pass through them easily. Eventually, fine soil particles may adhere within the seams, and thus, the wall becomes less permeable to groundwater flow. In very coarse, sandy soils, the wall may never seal unless the piling seams are first grouted, which adds to the overall cost. Corrosion of the steel from chemical exposure due to soil and groundwater contaminants can be reduced by the use of galvanized steel or other steel coatings at an increased cost; however, driving operations may damage the coating material. In general, steel sheet piling cut-off walls tend to be more expensive and probably less effective than slurry walls. Therefore, the use of sheet piling cut-off walls is not considered a feasible interim action technology and is eliminated from further consideration.

3.2.3.6 Groundwater Interception and Treatment

A successful containment technology that has been used at RMA is groundwater interception and treatment. Groundwater extraction wells are pumped to create a reverse hydraulic gradient, thereby limiting the migration of contaminants by reducing the movement of the groundwater. Extracted water is treated and reinjected.

Groundwater extraction and treatment as a containment technology is usually used in conjunction with a slurry wall. The slurry wall can either be constructed perpendicular to the groundwater gradient, downgradient of the contaminant source, or it can be constructed 360° around the entire source area. When the slurry wall is constructed downgradient of the source, the groundwater is extracted upgradient of the well to maintain a reverse hydraulic gradient. When the 360° slurry wall is constructed, water is extracted from inside it. Creating a lower potentiometric surface inside the slurry wall prevents exfiltration of the groundwater through the slurry wall, which could result from possible construction imperfections. This technology has been successfully implemented at several sites at RMA; however, because other containment technologies are available for this site that do not require long-term operations or the handling of secondary waste streams (specifically arsenic sludge from the water treatment), it will not be considered further for the M-1 Settling Basins.

3.2.4 Source Collection

Excavation of contaminated soils is a standard approach to source collection at hazardous waste sites. Excavation is a prerequisite to disposal of soils in a landfill (on site or off site) or treatment, and is also required for some methods of soil washing or chemical fixation. Typically, excavation depths are limited to the depth of the groundwater table. Since the depth to the water table at the site varies during the year, scheduling of the excavation operations during the low water table season would be appropriate. If groundwater is encountered, some method of dewatering may be necessary (subsection 3.2.7.1).

Temporary excavations will typically be performed with side slopes of 1 vertical to 1 horizontal (1:1) to protect workers and equipment within the excavation in accordance with Occupational Safety and Health Administration (OSHA) requirements. This technology is feasible for use at the M-1 Settling Basins.

3.2.5 Treatment

The contaminated soils and sludges at the M-1 Settling Basins can be treated to reduce their mobility, toxicity, or volume. This treatment may be physical, chemical, biological, or a combination. This treatment can be accomplished with or without source collection methods described in the previous section. Treatment methods not requiring source collection are called in-situ methods and are described in subsection 3.2.5.1. Onsite treatment methods are described in subsection 3.2.5.2. Offsite treatment technologies are discussed in subsection 3.2.5.3.

3.2.5.1 In-situ Treatment Technologies

Three technologies are identified as in-situ treatment measures:

- In-situ vitrification
- In-situ chemical fixation
- In-situ soil washing

3.2.5.1.1 In-situ Vitrification. In-situ vitrification is a thermal treatment process that consolidates contaminated soils into a hard, impermeable, stable glass and/or crystalline product. The process passes an electric current among four electrodes placed in the ground in a square array. Heat from the electric current melts the soil and rocks and pyrolyzes organic materials. During the process, metallic and other inorganic materials are dissolved into or encapsulated in the vitrified mass.

The system reaches up to 3600 ° F, well above the 2000 ° F to 2500 ° F fusion temperature of soils. Since soil is not electrically conductive once the moisture has been driven off by initial heatup, a conductive mixture of flaked graphite and glass frit is placed between the electrodes as a "starter path." As the graphite is consumed, the current is transferred to the molten soil, which becomes progressively more conductive. When the electric current is cut off, the molten volume cools and solidifies. Because of the intense chemical and structural changes, subsidence accompanies cooling, and some backfilling and regrading are required.

The process generates considerable gases from volatile constituents in the soil, by-product gases from pyrolysis of larger organic molecules and volatile metals. The gases and by-products migrate to the surface of the vitrified zone where they combust in the presence of oxygen. A gas collection hood and offgas treatment system control gas emissions containing volatile metals and products of incomplete combustion.

The process has been applied at both bench and field scale on electroplating wastes, dioxin waste, radioactively contaminated soils, and a waste pile of mixed containerized organic wastes. The typical field-scale energy consumption ranges from 500 to 1,000 kW per 100 tons of waste. This technology may be effective for the M-1 Settling Basins.

3.2.5.1.2 In-situ Chemical Fixation. Chemical fixation technology for either metal or organic contaminants is potentially available without excavation of soils. At least one supplier has demonstrated a pilot-scale system to drill and blend waste material in place with a fixative or bonding agent. The process consists of drilling into the waste or soil with a boring rod with two liquid channels. While the rod is being lifted, bonding agents supplied by grout pumps are injected through the channels and mixed, eventually setting into a vertical cylindrical column of impermeable inorganic crystalline or cemented material.

This technique is still in the experimental stage, and the test system has been designed for an organic contaminated soil. No demonstration is available for metals that are present at the M-1 Settling Basins. Therefore, this technology has not been selected for further evaluation.

3.2.5.1.3 In-situ Soil Washing. In-situ soil washing has been applied at the test or pilot level for both organic and metal contaminated soils. The process consists of saturating the contaminated zones with chelate, solvent, or diluent via injection wells, and collecting the introduced fluid and entrained contaminant via a second series of wells, producing a washing circuit.

Several potential problems may be encountered with this approach. First, the chelate or solvent, by rendering the contaminants soluble, may spread the contamination if the collection system is not completely effective. Second, because of the uncertainties of distribution patterns, large quantities of solutions must be applied. Third, contact patterns and residence time are less certain than in an above-ground system. For these reasons, in-situ soil washing is not retained for further consideration.

3.2.5.2 Onsite Soil and Sludge Treatment Methods

Three technologies are identified as onsite treatment measures for contaminated soil and sludge:

- Chemical fixation/stabilization
- Soil washing/solution mining
- Vitrification

3.2.5.2.1 Chemical Fixation/Stabilization. Chemical fixation/stabilization refers to treatment methods that surround or encapsulate waste components in a stable inorganic matrix. The treatment additives are selected to:

- Minimize contaminant spread by agglomerating the wastes and reducing the transfer surface area
- Reduce the solubility, toxicity, or mobility of hazardous components
- Solidify or otherwise improve the handling or structural characteristics of the waste

Stabilization generally refers to those processes that add materials to change the pH, limit the solubility or mobility, or otherwise chemically alter the environment around the contaminant molecule. This process may solidify the waste or contaminated soil, or may leave it either friable or close to its original consistency after treatment.

Chemical fixation involves applying additives of the type and quantity that will produce a monolithic block of high structural integrity or a friable product. This process produces a stable inorganic polymer lattice that includes the contaminants in the lattice.

Chemical fixation/stabilization can be accomplished by various means; most are referred to in terms of the additives used to treat the waste. The two approaches discussed herein are the cement process,

which is a chemical process, and the pozzolanic silicate process, which is a physical process. Both processes will require a solids-handling operation consisting of the following basic steps:

1. Excavation of contaminated soils
2. Temporary storage on a pad on site
3. Blending with additives in a high shear mixer or pug-type mill
4. Reaction time in a solidification cell
5. Replacement into either the excavation pit or a landfill

3.2.5.2.2 Cement Process. The cement process is based on the addition of primarily portland cement or other cementitious materials and water, which will mechanically incorporate waste components into a rigid matrix when it cures. However, many wastes, especially organic contaminants remain leachable from the cured cement since they are not chemically bound. This process elevates the bulk pH to a level at which most metal ions are in the insoluble hydroxide or carbonate form. The actual cement matrix is a calcium-silicate hydrate.

The metal salts are not stable over a wide pH range, and potentially, even precipitation is acidic enough to initiate leaching. This process, when used alone, is generally not effective on some metal salts such as salts of lead, copper, and zinc. Hence, the cement process is usually used in conjunction with other processes as a final hardening agent.

3.2.5.2.3 Pozzolan Silicate Process. The pozzolan process forms a matrix from fine ground siliceous materials such as fly ash, blast furnace slag, or kiln dust with calcium oxide or gypsum and water. Silicate content is often augmented by addition of solutions of sodium or potassium silicate. As with the cement process, this process increases the weight and volume of the waste. However, depending on additive ratios, the product consistency may remain clay-like to friable rather than a cemented solid.

This system has been applied to both divalent metal contaminants and organic contaminants in field-scale remediations. This system is effective in binding heavy metals because they chemically react with the silicate materials as the initiators of the gel or setting process. The presence of oil and grease may interfere with the reaction, as do some sulfates, dichromates, and carbohydrates. Oil and grease are not expected to be factors in the treatment at the M-1 Settling Basins.

Both cement and pozzolan processes utilize readily available materials and conventional mixing equipment. Some combinations of chemical fixation or stabilization methods may be feasible for the M-1 Settling Basins.

3.2.5.2.4 Soil Washing/Solution Mining. Soil washing, also referred to as solution mining when performed as a batch operation, consists of mixing contaminated soil with a chelating agent or solvent to dissolve and remove the entrapped metals and organics. In the batch process, a tank or plastic-lined pit is filled with excavated soils in a working pile or heap. The pile is sprayed and flooded with the treatment solvent or chelate and the leachate collected and recycled. The solution is recycled until the contaminant concentrations in both the soil and the treatment solution are in equilibrium, and no further extraction from the soil will occur. The solution is then diverted and solids extracted via vacuum filtration or other dewatering process. The remaining liquids are either processed for reuse or chemically or thermally destroyed. The filtrate sludge is suitable for recycling in a smelting furnace for recovery of the metal constituents and thermal destruction of any organic content. The solution process significantly reduces the volume of metal-bearing solids to a smaller amount more economically and safely transported to an offsite recovery treatment/disposal facility.

The batch process can be carried out completely on site except for any smelter recovery step. This process has been applied to ore piles in the precious and commercial metals industry and is referred to as "heap leaching."

Soil washing can also be conducted as a continuous process by utilizing a froth flotation. In this application, the soils are screened prior to the addition of cleansing agents and water to form a slurry. This slurry is routed to parallel flotation cells. Then the contaminated froth is drawn off the top, and the slurry is pumped to wet-scouring tanks for a final water rinse. The cleaned slurry is then dewatered by filtration, leaving a soil that can be returned to the site or disposed of as clean fill. The contamination is collected in the form of a concentrated sludge, which can be incinerated or landfilled. This process configuration is usually applied to organics-contaminated soil.

This process has been conducted on a bench- and pilot-scale basis in Europe with excellent removal efficiencies reported on soils with concentrations of contaminants in the range of those at the M-1 Settling Basins (Brochine, undated). This process can also be applicable for metals removal. However, the process configuration for metals removal is normally a countercurrent decantation process. This approach offers the possibility of addressing both metals and organics.

The waste material in the M-1 Settling Basins has been shown to have an alkaline pH. An excessive amount of acid would be required to dissolve the calcium salt and reduce the pH before the metals could be solubilized and washed from the soil, making soil washing an inefficient method of treating the M-1 Settling Basins waste. There is also the possibility that arsine gas may be formed during this process. Therefore, this process will not be considered further.

3.2.5.2.5 Vitrification. Vitrification is a thermal treatment technology used to transform the physical and chemical characteristics of a hazardous solid waste so that the organic contaminants are destroyed, and treated residues contain primarily inorganic hazardous material immobilized in a vitreous mass. Vitrification can be applied in-situ, as described in subsection 3.2.5.1.1, or above ground as described herein. Inorganic contaminants should remain entrained in the glass melt, while any organic compounds are oxidized at the reactor temperature of approximately 3000 ° F.

The reaction chamber is divided into upper and lower refractory-lined sections. The upper section accepts the waste feed via gravity and contains gases and other products of pyrolysis; the lower section contains a two-layer molten zone for both the metallic and siliceous melts. The feed is gravity fed into the reactor by conveyor. The offgas and particulates are drawn off by an induction fan to an offgas treatment system. This system usually consists of a cyclone, baghouse, acid gas scrubber, and if necessary, a carbon filter. Particulate and gas streams, as well as the carbon filter, can be recycled to the reactor.

There are several vitrification processes currently available; each has characteristic reaction conditions (e.g. temperature, oxygen content) and solids-handling methods. One vitrification process is commercially available in full-scale operation. However, this process has not been applied to volatile metals, and the vendor currently has no plans to modify the process to treat volatile metals. Therefore, this technology will not be retained for further evaluation.

3.2.5.3 Offsite Treatment

One technology, chemical fixation/stabilization, is identified as an offsite treatment measure.

3.2.5.3.1 Offsite Chemical Fixation/Stabilization. Chemical fixation/stabilization refers to a treatment method that surrounds or encapsulates waste components in a stable inorganic matrix. To utilize this option off site would involve the following basic steps:

1. Excavation of contaminated soils and sludges
2. Transportation to a treatment facility
3. Blending with additives in a high shear or pug-type mill
4. Reaction time in a solidification cell
5. Burial in an existing commercial RCRA-landfill

This process uses readily available materials and equipment and is technically feasible.

3.2.6 Temporary Storage/Disposal

Soil, concentrated sludges, and other solid wastes may require disposal before or after treatment. This disposal can be either onsite temporary storage or offsite disposal at a properly permitted facility. This section evaluates technologies for the temporary storage/disposal of soils, sludges, and other solid waste.

3.2.6.1 Onsite Temporary Storage

Two technologies have been identified for onsite temporary storage:

- Temporary waste pile
- Solid waste landfill

3.2.6.1.1 Temporary Waste Pile. Solid wastes that have been classified as hazardous under 40 CFR Part 261 would be stored in a temporary waste pile that substantially complies with the design requirements of 40 CFR 264, Subparts L and N, requirements for such a facility. Design requirements currently include double liners, leachate collection and treatment, capping, surface water control, and a groundwater monitoring system. This technology is feasible for temporary storage.

3.2.6.1.2 Solid Waste Landfill. A selected soil/sludge treatment technology may be effective in declassifying the material as hazardous as defined in 40 CFR Part 261. Therefore, hazardous waste storage requirements would be unnecessary. Temporary storage of solid waste on site in a facility designed to meet EPA's solid waste landfill requirements is feasible.

3.2.6.2 Offsite Disposal

Two alternative methods are available for offsite disposal of soils/sludges:

- Disposal in a hazardous waste landfill
- Disposal in a solid waste landfill

3.2.6.2.1 Disposal in a Hazardous Waste Landfill. Contaminated soils and sludges or treated solid waste streams from treatment processes can be disposed of off site in a commercial hazardous waste landfill. The nearest, fully permitted hazardous waste facility to RMA is the USPCI Grassy Mountain landfill near Clive, Utah. Offsite disposal will require excavation and management of groundwater through one or more of the treatment technologies described in subsection 3.2.7. This is a feasible technology for the M-1 Settling Basins.

3.2.6.2.2 Disposal in a Nonhazardous Solid Waste Landfill. Nonhazardous solid wastes from soil/sludge treatment processes can be disposed of in a nonhazardous waste landfill. Several of these exist in the area. Disposal at a facility with less stringent controls than a hazardous waste landfill will require that the waste transported off site be delisted and considered nonhazardous. Since there will be some nonhazardous debris generated in these operations, this will be considered a feasible technology.

3.2.7 Dewatering and Water Treatment

The objective of this IRA is to mitigate the threat of release from the M-1 Settling Basins. Groundwater remediation is beyond the scope of the IRA. Therefore, water treatment will only be conducted if implementation of the selected alternative requires dewatering operations. It has been assumed that the chosen IRA alternative can be implemented during the dry season, which would make dewatering and water treatment unnecessary. If this is impossible, the following dewatering and water treatment alternatives will be considered.

3.2.7.1 Dewatering Process

Contaminated soils/sludges can be dewatered by using one or more of the following processes:

- Pumping from wells
- Pumping from collection trenches excavated below the water table
- Excavation and filtration

3.2.7.1.1 Groundwater Well Pumping. Groundwater pumping techniques involve the active manipulation and management of groundwater to contain or remove a plume or to adjust groundwater levels to prevent the formation of a plume. At the M-1 Settling Basins, the objective is to lower the contaminated groundwater table a sufficient depth to allow for effective soil remediation. This soil remediation method may be in-situ or may require excavation. In either case, the presence of groundwater may limit the effectiveness of the chosen methods. Types of wells used in the management of contaminated groundwater include wellpoints, suction wells, ejector wells, and deep wells. The selection depends on groundwater depth as well as the hydrologic and geologic characteristics of the aquifer.

This method of groundwater control is a technically feasible method of dewatering the soil beneath the M-1 Settling Basins.

3.2.7.1.2 Subsurface Drains. Subsurface drains are usually any type of buried conduit used to convey and collect aqueous discharges by gravity flow. They create a zone of influence much like an extraction

well. Drains have distinct advantages over wells for use in shallow aquifers, such as at the M-1 Settling Basins. Pumping on a shallow well field in strata of low or variable hydraulic conductivity can be problematic if a continuous hydraulic boundary is necessary. Also, operation and maintenance costs are generally lower for drains with respect to wells.

The main components of a drainage system are a drain pipe for conveying flow to a wet well, a gravel pack around the drain pipe, a filter to prevent clogging (if fines are a problem), backfill, and a manhole or wet well for groundwater collection and pumping.

This method of groundwater control is a technically feasible, potentially cost-effective method of dewatering the soil beneath the M-1 Settling Basins.

3.2.7.1.3 Filtration. Soils and sludges can be dewatered after excavation by using a couple of techniques. Soils can be allowed to drain within a bermed area after excavation. The drained water is collected in a low-point sump for subsequent water treatment. This is effective for removing only a fraction of the associated groundwater but may be applicable for processes requiring water, for example, chemical fixation/stabilization.

If the excavated solids require a greater level of dewatering for subsequent processing, this can be accomplished by using equipment such as a vacuum filter. This filtration operation can be run in a batch or continuous mode. In a continuous mode, the soil/sludge is fed through a hopper and a rotating drum equipped with a cloth filter medium. A vacuum is drawn on the interior of the drum that pulls water through the cloth media. The dried soil/sludge is then separated from the cloth medium either by a stationary knife or by gravity.

This type of filtration can typically produce a dried sludge with water content as low as 10 percent. This technology is feasible for alternatives that require significant dewatering prior to solids processing.

3.2.7.2 Water Treatment Processes

Historical information and data from the spring 1989 investigation indicate that groundwater in the vicinity of the M-1 Settling Basins contains many of the organic and inorganic compounds detected in the South Plants area. Predominant classes of groundwater contaminants include arsenic, mercury, organochlorine pesticides, volatile organic compounds, and semivolatile organic compounds. Whether or not the M-1 Settling Basins contribute to this aquifer degradation does not affect the conclusion that this water, once extracted, will require treatment prior to either reinjection or disposal. The following alternatives for water treatment will be discussed in this section.

- Carbon adsorption
- Rotating biological contactor
- Fixed-bed bioreactor
- Powdered activated carbon/activated sludge
- Ultraviolet-enhanced chemical oxidation
- Chemical precipitation/flocculation
- Ion exchange
- Activated alumina

3.2.7.2.1 Carbon Adsorption. Granular activated carbon (GAC) adsorption is commonly used for removal of organics from water. The removal efficiency depends on factors such as the polarity, solubility, and size of the molecules to be removed. The adsorption occurs in packed columns with flow rates and contact times determined by properties of the contaminants to be removed.

The carbon must be regenerated when saturated or when the effluent reaches unacceptable levels of contaminants. At these times, the bed of carbon is removed from the packed column and replaced with new material. The saturated carbon is thermally treated in a regeneration furnace for destruction of adsorbed organic compounds and reused. Poor adsorbability or higher contaminant concentrations result in frequent regenerations.

The volatile halogenated organics present in the alluvial aquifer in the vicinity of the M-1 Settling Basins (see Section 2.0) are among the least sorbable species with reference to GAC. These compounds can be effectively removed from groundwater streams if present in dilute concentrations. However, the cost-effectiveness of adsorbing high concentrations of volatile halogenated compounds from groundwater is limited because breakthrough of the carbon beds would occur by one or more species long before the carbon is saturated. This would result in frequent carbon changeout producing large volumes of waste solids for regeneration or disposal. For this reason, GAC will not be considered further.

3.2.7.2.2 Rotating Biological Contactors. Rotating biological contactors (RBC) are considered for groundwater treatment because of their relatively low energy use and simple operation. An RBC system consists of a series of disks covered with a film of active biomass that is partially submerged in the wastewater. Disk rotation alternately exposes the attached biomass to the substrate-rich wastewater and to the atmosphere. Substrate (including hazardous constituents), measured as soluble biochemical oxygen demand or chemical oxygen demand (BOD₅ or COD), is oxidized and converted to a new biomass, soluble metabolic by-products, and gaseous end products. Sequential groups of disks, called stages, are designed to meet specific effluent requirements based upon soluble BOD removal in each stage.

Important controlling factors of the RBC system are influent substrate concentration, surface hydraulic load, disk rotational speed, effective disk surface area, submerged disk depth, liquid retention time, wastewater treatment temperature, and number of stages. Therefore, the prediction of achievable effluent concentrations from an RBC wastewater treatment system is difficult because of the number of the process operating parameters.

Studies indicate the RBC process for municipal wastewater is approximately first order with respect to BOD concentration; that is, the rate of bio-oxidation is proportional to the amount of oxidizable organic matter remaining. The design of the standard municipal RBC process is primarily based on the hydraulic loading rate (gal/day/ft²) and the organic loading (lbs BOD/day/ft²). Temperature can affect performance of the fixed-film process, as it influences substrate removal rates, oxygen saturation values (also mass transfer driving forces), and the diffusivities of oxygen and substrate. At wastewater temperatures of 13 °C (55 °F), changes in hydraulic or organic loading have been shown to result in significant changes in BOD removal.

The staging of RBC units is a major design element. The simulation of plug flow operation by proper staging results in a higher treatment efficiency. RBC facilities are typically designed with four or more stages operating in series depending on the substrate removal desired.

General advantages of an RBC system:

- Simple operation and maintenance
- High resistance to shock and hydraulic loading
- Successful operation with or without air supply
- Low sludge production with good sludge settleability and dewaterability
- Low power consumption
- Low heat loss

Major disadvantages of an RBC system:

- It does not address the arsenic in the groundwater (arsenic may be toxic to biomass) and is inefficient in removing chlorinated hydrocarbons
- The technology is relatively unproven for the conditions at RMA
- Engineering costs are higher because of the process development studies required (i.e., pilot studies)

Since an RBC does not significantly reduce the arsenic concentration in the water, it would have to be used in conjunction with another treatment step design to reduce arsenic concentrations to acceptable discharge levels. Because this technology will require feasibility testing, it will not be retained for further consideration for this IRA.

3.2.7.2.3 Fixed-Bed Bioreactor. Conventional, flow-through aeration basins (lagoons and tanks) are of limited effectiveness in biodegradation of low concentration influent waters. The primary limitation consists of the inability of microorganisms to find sufficient organic substrate to feed upon in a high-volume, low-concentration system, i.e., insufficient contact between biomass and contaminants.

Fixed-bed bioreactors are adaptations of aerobic bioreactors that allow the processing of diluted wastewaters. A fixed-bed reactor consists of one or more tanks or vessels fitted with a high surface area plastic or other fill material, which is baffled or compartmentalized to reduce throughput velocity and maximize retention time. Microorganisms are seeded at a startup with nutrients and carbohydrate solution to encourage initiation of a biomass growth on the fill material surface. Feedwater undergoes intimate contact with the fill surfaces over a long enough time period to allow microbes to locate and degrade contaminant molecules. Aeration is augmented by bottom spargers or diffusers.

Fixed-bed systems are available in modular portable tank systems with built-in aerators and fill media, allowing relatively simple mobilization/demobilization. These systems have been effective at several large-scale groundwater remediation sites. This technology is feasible as part of an overall groundwater treatment system, though other steps will be required for arsenic removal.

3.2.7.2.4 Powdered Activated Carbon/Activated Sludge. Powdered activated carbon (PAC) addition to a conventional activated sludge wastewater treatment system can significantly improve the performance of the system because removal of recalcitrant organic compounds is improved. Biological treatment of municipal and industrial wastewater is a well-proven technology. However, process performance can be detrimentally affected by low organic loading and the presence of refractory compounds that may pass through the system. Addition of a powdered carbon can improve performance by adsorbing these components and providing a longer residence time for biological metabolism. In a biologically active, powdered activated carbon treatment (PACT) system, powdered carbon is added to a conventional activated sludge system. The powdered carbon adsorbs organic contaminants that have not been degraded biologically and is removed from the wastewater in a clarifier. The clarifier underflow is recycled back to the contactor tank, with a small side stream removed for disposal. The spent carbon sludge must be disposed of at an EPA-permitted disposal facility. The spent carbon may

also be regenerated on site using a wet air oxidation process; however, for intermediate water throughput rates (500 to 1,000 gpm), offsite disposal of the spent carbon sludge is more economical.

PACT installations are successfully being used for the treatment of municipal, industrial, and mixed municipal/industrial wastes (Zimpro, Inc. 1987). Incineration and/or landfilling of the sludge is employed at a number of these installations.

Ability to vary the PAC dosage gives flexibility to the process. At RMA, the dose could vary with the flow rate or concentration to provide control over effluent quality. This would enable adjustment of treatment to achieve necessary removal levels.

The advantages of this treatment method are:

- Fast rate of adsorption
- Easy-to-control removal efficiency
- Lower carbon requirement than GAC

Disadvantages of this treatment technology are:

- High capital costs
- Problems with the handling of spent carbon sludge
- Does not remove arsenic

In general, the treatment efficiency of a PACT system approximates that of other biological treatment processes. However, the PACT approach generates a considerably larger quantity of secondary waste, i.e., sludge, to achieve comparable treatment results. Based on the availability of equivalent treatment technologies generating less waste, PACT will not be evaluated further.

3.2.7.2.5 Ultraviolet(UV)-enhanced Chemical Oxidation. In theory, organic matter in a wastewater stream can be completely destroyed by chemical or thermal oxidation. The by-products of complete oxidation of a hydrocarbon are water and carbon dioxide. Thus, it should be theoretically possible to convert even the most toxic hydrocarbons to innocuous chemicals that would not have adverse environmental effects.

There are many methods of oxidizing organic chemicals. Thermal methods are the most familiar, but they are unsuitable for diluted, high-volume liquid waste streams because of the large energy requirements for vaporizing the bulk liquid. Therefore, for most diluted liquid streams, some method

of chemical oxidation is preferred to remove the objectionable components from the wastewater. The most suitable chemical oxidation processes identified for this study were UV-enhanced oxidation by ozone or hydrogen peroxide. These processes have been shown to achieve complete destruction of target organics when operated under optimal conditions.

Ozone is a powerful oxidizing agent that has traditionally been used in wastewater treatment systems as a disinfectant and viricide. Ozone is produced when a high voltage is imposed across a discharge gap in the presence of a gas containing oxygen. Because ozone is a relatively unstable gas, it must be generated on site from air or pure oxygen. In a pure oxygen system, offgases from the ozone contact chamber can be recycled back to the ozone generator for more efficient oxygen use. In an air system, offgases are usually vented to the atmosphere. Ozone quickly reverts to oxygen in the environment and does not pose a significant environmental impact when used in an air-fed system.

UV light has been shown to markedly increase the rate of oxidation in ozonation reactors treating wastewaters. This is attributed to the higher energy of the UV light excitation of the organic molecules. Unfortunately, the use of UV light enhances only the rate of oxidation but not the efficiency. Thus, the quantity of ozone required will not be reduced appreciably by UV radiation.

Hydrogen peroxide, when exposed to UV light, readily reacts to form hydroxyl radicals. These radicals are also strong oxidants that can similarly react with organic contaminants in water. The choice of optimal oxidant and operating conditions can only be determined after a bench-scale test. The selection of an oxidant (ozone or hydrogen peroxide) is addressed later in the selection process. An additional post-treatment step would be required for the metals contamination in the water because UV-enhanced chemical oxidation does not remove metals. This technology is feasible for the destruction of organics in groundwater.

3.2.7.2.6 Chemical Precipitation/Flocculation. Chemical precipitation/flocculation involves adding agents to remove the contaminants from solution, followed by sedimentation or other physical separation to remove the resulting insoluble particles from the water. Chemicals added to remove contaminants from solution perform either of the following:

- Increase or decrease the system pH to a level where the contaminant is less soluble
- React with the contaminant to form an insoluble salt
- Shift the solubility equilibrium of the contaminant to make the existing compound insoluble

Additionally, polymer flocculants are frequently added to help agglomerate the resulting suspended particles into "floc" or larger particles that can be more easily removed by sedimentation, filtration, centrifugation, or other mechanical means.

Removal of particulates is generally accomplished by long-residence time sedimentation (settling) in a clarifier. The combination of microfiltration and recycling of the concentrate through the reagent mix portion of the system until large settleable particle size develops is also applied to metal salt systems. Both approaches often require subsequent dewatering operations for reduction of the generated sludges. Dewatering is commonly performed by pressure filtration using either a belt-filter press or a plate-and-frame filter. The final sludge cake (approximately 30 to 50 percent solids) would be landfilled with or without chemical fixation/stabilization. This technology is technically feasible for metals removal.

3.2.7.2.7 Ion Exchange. Ion exchange treatment removes selected ions from water by electrochemically collecting them on a polymeric surface containing sites of opposite charge. Systems suited to water treatment generally contain one or more pressure vessels (exchangers) filled with "resin beds" consisting of beads of various polymer resins containing either cationic or anionic sites. When the water or aqueous waste has passed through the beds long enough to saturate the sites, flow is stopped and the beds "regenerated" by contacting with a regenerate solution (acids, caustic, or other solutions as appropriate) to remove the contaminant ions. The spent regenerate is either processed for reuse, concentrated for recovery of the contaminants, or processed for disposal.

Ion exchange is a potentially feasible technology for the removal of arsenic.

3.2.7.2.8 Activated Alumina. Arsenic can be adsorbed from a water stream on the surface of activated alumina. Activated alumina is essentially a highly porous form of aluminum oxide. Aluminas are available both as granules and as fine powders; hence, they provide a large surface area and adsorptive capacity per unit volume (Considine 1974). This technology is technically feasible and is currently in use with GAC for arsenic removal in the Building 1727 sump treatment system located in Building 1713 at RMA (ESE 1988).

3.2.7.3 Treated Water Disposal

There are two onsite methods of disposal for treated water: reinjection through wells and reinjection through percolation beds or trenches. Discharge to a storm drain is the only available offsite disposal option.

3.2.7.3.1 Reinjection through Wells. The conventional method of injecting fluids or reinjecting extracted water into an aquifer is the use of injection wells screened at strategic depths. However, that injection water will probably be laden with suspended and microbial solids unless it has first been filtered. Filtering can add considerably to total water treatment costs. If the injected water is not filtered, injection well screens are likely to clog readily with solids and will not be dependable for long-term service. In addition, screens provide surface area for microbial growth and may plug, even with fluids that have been filtered of solids and microbes. For these reasons, this technology will not be considered further.

3.2.7.3.2 Reinjection through Percolation Beds or Trenches. Discharge water can be pumped or drained over a bed of crushed rock or gravel in order to enhance its percolation through the vadose zone. The percolation bed is a simple technology that is more reliable than injection wells, since it is less susceptible to fouling resulting from microbial growth.

3.2.7.3.3 Discharge to Storm Drain. Treated water can be routed to the nearest storm drain which is equivalent to surface water discharge. Surface water discharge at RMA ultimately outfalls to the south fork of the Platte River.

Surface water discharge of treated effluent water would require that the effluent concentrations meet the National Pollution Discharge Elimination System (NPDES) outfall limits of the RMA.

3.3 SUMMARY OF RETAINED TECHNOLOGIES

Tables 3-3 and 3-4 summarize the available technologies. Several identified technologies were evaluated as not being applicable based on technical implementability. The remaining technologies are used to formulate the alternative remediation scenarios of Section 4.0.

TABLE 3-1
IDENTIFICATION OF POTENTIAL TECHNOLOGIES
FOR SOILS AND SLUDGES
M-1 SETTLING BASINS

Response Action	Interim Action Technology	Process Description	Site * Rating	Comments	Unit Cost
Monitoring	Soil Boring/ Trenches	Sampling/ Analysis	A	Typically used to determine vertical and lateral extent of contamination	\$5,000
	Lysimeters	Sampling/ Analysis	A	For sampling leachate in the vadose zone	\$300-400
Institutional Controls	Access Restrictions	Fencing	A	Will limit site access	\$10/LF
In-place Containment	Surface Capping	Multilayered Cap	A	Typically consist of clay, synthetic, and drainage layers	\$30-50/yd ²
		Clay Cap	A	Requires grading and surface cover; uncovered cap may crack due to exposure	\$5-15/yd ²
		Synthetic Liner	NA	Highly susceptible to deterioration if not protected	\$4-10/yd ²

*A = applicable NA = not applicable

TABLE 3-1 (Continued)

Response Action	Interim Action Technology	Process Description	Site * Rating	Comments	Unit Cost
In-place Containment (Continued)		Asphalt	A	Effective as erosion protection; imperviousness may degrade as a result of weathering and cracking	\$4-8/yd2
		Concrete	NA	Excessively rigid, may crack, expensive	\$20-50/yd2
	Surface Control	Soil Stabilization	A	Improves erosion resistance, may decrease infiltration	\$3-5/yd2
		Grading	A	Controls runoff and runoff; inexpensive, reduces erosion	\$0.5-1.0/yd2
		Dikes/Berms	A	Controls runoff and runoff; inexpensive	\$2-5/yd3
	Vertical Barriers	Slurry Wall	A	Proven technology; shallow confining layer at 20 ft	\$5-15/R2
		Grout Curtains	A	Low quality control for field implementation	\$6-10/R2
		Sheet Piling	A	More pervious than slurry wall, installation difficult in dense or cobbly soils	\$10-20/R2

* A = applicable NA = not applicable

TABLE 3-1 (Continued)

Response Action	Interim Action Technology	Process Description	Site * Rating	Comments	Unit Cost
Source Collection	Excavation	Backhole	A	Hazardous soils excavation has occurred at the arsenal	\$1-3/yd3
In-situ Treatment					
		Biological	NA	Sludge composition is very high in mercury and arsenic, which will inhibit effectiveness of biodegradation	Low <\$100/yd3
		Vitrification	A	Bench test performed on M-1 Basin sludge; resultant glass passed EPTOX test	\$400-700/yd3
		Chemical Fixation	A	Effective on high concentrations of metal contamination	\$45-65/yd3
		Soil Washing	A	More effective on metals than on organics; bench testing recommended	\$150-200/yd3
Onsite Treatment	Biological	Landfarming	NA	Currently testing on OCPs; metal contamination will inhibit effectiveness of biodegradation	\$25-40/yd3

* A = applicable NA = not applicable

TABLE 3-1 (Continued)

Response Action	Interim Action Technology	Process Description	Site * Rating	Comments	Unit Cost
Chemical		Bioreactor	NA	Agitation speeds degradation rate; metals will inhibit effectiveness	\$25-45/yd3
		Fixation	A	More effective on metals than organics; quality control fairly high for small particle sizes	\$35-100/yd3
		Solvent Extraction	NA	Proven effective on organics in soil; limited metals removal	\$60-80/yd3
		Solution Mining (Chelation)	A	Typically used for metal extraction in mining; limited recovery levels	\$60-80/yd3
		Oxidation	NA	Effective in lab studies; difficult to duplicate in field	\$100-125/yd3
Physical		Dechlorination	NA	Bench and pilot test demonstrated successful destruction of OCPs in soils and sludges; no metals treatment	\$100-150/yd3
		Separation	A	Separation techniques may be used to remove liquids from the sludge (i.e., centrifuge)	

*A = applicable NA = not applicable

TABLE 3-1 (Continued)

Response Action	Interim Action Technology	Process Description	Site * Rating	Comments	Unit Cost
	Incineration	Thermal Stripping	NA	Effective for volatiles & semi-volatiles, will not address metals	\$150-200/yd3
		Pozzolonic Fixation	A	Will reduce contaminant mobility by reducing soil surface area	\$50-100/yd3
		Rotary Kiln	NA	Make up fuel required; possible negative community reaction	\$400-800/yd3
		Fluidized Bed	NA	Make up fuel required; possible negative community reaction	\$400-800/yd3
		Infrared Moving Bed	NA	Make up fuel required; possible negative community reaction	\$400-800/yd3
Offsite Treatment	Chemical	Fixation	A	More effective on metals than organics; quality control fairly high for small soil particle sizes	\$300-400/yd3

*A = applicable NA = not applicable

TABLE 3-1 (Continued)

Response Action	Interim Action Technology	Process Description	Site * Rating	Comments	Unit Cost
Onsite Temporary Storage		Waste Pile	A	Will provide containment for the soils and sludges	\$50-60/yd3
		Solid Waste Landfill	A	Appropriate for nonhazardous materials	\$40-60/yd3
Offsite Disposal	Landfill	Hazardous Waste	A	Appropriate for smaller volumes and residual sludges from treatments	\$100-500+/yd3
		Solid Waste	A	Applicable for nonhazardous or delisted waste	\$1-15/yd3

* A = applicable NA = not applicable

TABLE 3-2
IDENTIFICATION OF POTENTIAL TECHNOLOGIES FOR WATER
M-1 SETTLING BASINS

Response Action	Interim Action Technology	Process Description	Site * Rating	Comments	Unit Cost
Monitoring	Additional Sampling	Sampling/ Analysis	A	Sampling of existing site groundwater monitoring wells	\$5,000
	Installation Of Wells	Sampling/ Analysis	NA	Sufficient amount of monitoring wells exist on site	\$3-7000/well
Dewatering	Extraction	Pumping Wells	A	Proven technology for groundwater control and remediation	\$5-15k/well
	Subsurface Drains	Collection Trench	A	Applicable for shallow groundwater	\$75-100/R
	Filtration	Gravity Drain	A	Effective enough for some treatment processes; easily implemented	
		Vacuum Filter	A	Produces well-dried sludge; proven technology	
Water Treatment	Physical	Separation	NA	Only necessary if multiple liquid phases exist	cap = \$7-25,000 O&M = \$.05-.1/1K gal
		Air Stripping	NA	Only applicable on volatile organics	cap = \$20-75,000 O&M = \$.1-25/1k gal

* A = applicable NA = not applicable

TABLE 3-2 (Continued)

Response Action	Interim Action Technology	Process Description	Site * Rating	Comments	Unit Cost
		Reverse Osmosis	NA	Large organics could clog membrane; produces large volumes of concentrate	cap = \$250-500K O&M = \$.7-2/1k gal
		Act. Carbon Adsorption	A	Applicable on VOCs, marginally on OCPs, arsenic may adsorb onto activated carbon	cap = \$50-500k O&M = \$.5-2/1k gal
		Resin/ Adsorption	NA	Effective as carbon but more expensive; must regenerate or dispose offsite	cap = \$50-500k
		Activated Alumina	A	Effective on arsenic	
Biological		Rotating Bio. Contactor	A	Marginally effective on OCPs; expensive for remediation	cap = \$1.5-2.5 mil O&M = \$1-2/1k gal
		Aerated Impoundment	NA	Marginally effective on OCPs large area required	cap = \$20-50k O&M = \$0.2-0.4/1k gal
		Activated Sludge	NA	Marginally effective on OCPs; costly for remediation	cap = \$100-200k O&M = \$.1-2/1k gal
		Fixed Bed Bioreactor	NA	Fairly effective on OCPs; least costly of all bio treatment	cap = \$50-150,000 O&M = \$.1-4/1k gal

*A = applicable NA = not applicable

TABLE 3-2 (Continued)

Response Action	Interim Action Technology	Process Description	Site # Rating	Comments	Unit Cost
Chemical	PACT/Activated Sludge		A	Effective on OCPs proven technology; expensive	cap = \$2-4 mil O&M = \$.5-1/1k gal
					cap = NA O&M = >\$5/1K gal
	Dechlorination		NA	Laboratory tested; creates hazardous waste stream	cap = \$45-300K O&M = \$.5-2/1k gal
	UV/Ozone		A	Proven technology on OCPs; will not treat metals	cap = \$100k
	Chemical Precipitation		A	Not applicable on organics; but, effective for arsenic removal	
Thermal	Ion Exchange		A	Effective at metal removal; large sludge volume is generated	cap = >\$500k O&M = \$10/1000 gal
	Electrical Precipitation		NA	Success at some metals removal; arsenic removal efficiency questionable	cap = \$100k O&M = \$.2/1k gal
	Solar Evaporation		NA	Excessive land space required; negative community reaction	cap = \$25-50k O&M = \$.05-2/1k gal

* A = applicable NA = not applicable

TABLE 3-2 (Continued)

Response Action	Interim Action Technology	Process Description	Site * Rating	Comments	Unit Cost
Disposal	Offsite	Hazardous Waste Facility	NA	Costly; potential hazard and liability for offsite hauling and disposal	cap = \$25k O&M = \$5-50/1k gal
		POTW	NA	No current assess	cap = \$5k O&M = \$0.01-1/1k gal
	Onsite	Injection Well	A	Tendency to clog; effective if soils are highly transmissive	\$7-12,000/well
Offsite		Percolation Bed	A	Current injection method at RMA	<\$5,000
		Pond/Lagoon	NA	Not available	\$10000/yr
		Storm Sewer	A	NPDES permit impact	\$10-15,000/yr

*A = applicable NA = not applicable

TABLE 3-3
TECHNOLOGY SCREENING FOR SOILS AND SLUDGES
M-1 BASINS

Response Action	Interim Action Technology	Process Description	Retain for Alternatives (yes/no)	Screening Comments
Monitoring	Soil Boring/ Trenches	Sampling/ Analysis	YES	Confirmation samples may be necessary
	Lysimeters	Sampling/ Analysis	NO	No alternates require soil moisture monitoring
Institutional Controls				
	Access Restrictions	Fencing	YES	Perimeter fencing may be constructed around the M-1 Basins; incorporated with Alternative 3
In-place Containment				
	Surface Capping	Multilayered Cap	YES	A multilayered cap may be constructed alone or with a slurry wall.
		Clay Cap	NO	Unprotected clay may crack upon extended exposure; poor drainage
		Asphalt	NO	Asphalt alone will not be a sufficient cap, however, could be used as a protective liner for the designed cap

TABLE 3-3 (Continued)

Response Action	Interim Action Technology	Process Description	Retain for Alternatives (yes/no)	Screening Comments
	Surface Control	Soil Stabilization	YES	Soil stabilization techniques may be incorporated for erosion control to cement existing soil, enhancing runoff
		Grading	YES	Site grading will be incorporated to control surface drainage and divert runoff/runon to the source areas
		Dikes/Berms	YES	Will be incorporated for designs of temporary storage pads of soils as well as containment of site process treatment areas
	Vertical Barriers	Slurry Wall	YES	Alternatives 4 and 6 incorporate slurry wall technology for in-place containment of the M-1 Basins
		Grout Curtains	NO	Less effective than a slurry wall
		Sheet Piling	NO	Ineffective for gravelly sandy soil; potential for migration through joints
Source Collection	Excavation	Backhoe	YES	Excavation techniques will be implemented

TABLE 3-3 (Continued)

Response Action	Interim Action Technology	Process Description	Retain for Alternatives (yes/no)	Screening Comments
In-situ Treatment		Vitrification	YES	ISV will address both metals and organics; offgas treatment required to address OCPs and metals
		Chemical Fixation	NO	Quality assurance questionable for fixation of OCPs with low TCLP levels
		Soil Washing	NO	Process may spread contamination; uncertain contact patterns and residence times
Onsite Treatment	Chemical	Fixation	YES	Demonstrated on lab scale for arsenic, mercury and OCPs
		Solution Mining (Chelation)	NO	Applicable to metal contamination; however, ability for process to achieve necessary removal efficiency is questionable
	Physical	Pozzolonic Fixation	NO	OCPs are easily leachable; only decreases surface area of solids; matrix can be broken down
Offsite Treatment		Vitrification	NO	No vendor available to vitrify volatile metals
	Chemical	Fixation	NO	Preference for onsite treatment

TABLE 3-3 (Continued)

Response Action	Interim Action Technology	Process Description	Retain for Alternatives (yes/no)	Screening Comments
Offsite Disposal	Landfill	Hazardous Waste	YES	Appropriate for smaller volumes and treated sludges, or residual sludges from treatments
		Nonhazardous Waste	YES	Appropriate for nonhazardous materials (i.e., site debris)
Onsite Temporary Storage		Waste Pile	YES	Will provide maximum practical onsite containment
		Solid Waste Landfill	YES	Appropriate for nonhazardous materials

TABLE 3-4
TECHNOLOGY SCREENING FOR WATER
M-1 BASINS

Response Action	Interim Action Technology	Process Description	Retain for Alternatives (yes/no)	Screening Comments
Monitoring	Additional Sampling	Sampling/ Analysis	YES	Groundwater monitoring will continue; however no additional wells will be installed
Dewatering	Extraction	Pumping Wells	NO	Low yielding aquifer requires excessive number of wells
	Subsurface Drains	Collection Trench	YES	During excavation, surface trenches may be employed for dewatering prior to soil removal
	Filtration	Gravity Drain	YES	Effective enough for some treatment processes; easily implemented
		Vacuum Filter	YES	Produces well-dried sludge; proven technology
Water Treatment	Physical	Separation	YES	Sludge proven to phase separate after liquefaction
		Act. Carbon Adsorption	NO	Effective on OCPs but not on metals; could be effective if only a small volume of water is to be treated; high carbon usage with high concentrations of contaminants

TABLE 3-4 (Continued)

Response Action	Interim Action Technology	Process Description	Retain for Alternatives (yes/no)	Screening Comments
	Biological	Activated Alumina	YES	Has been used effectively for arsenic removal of RMA
		Rotating Biological Contactor	NO	Requires treatability testing; does not address arsenic contamination
		PACT/Activated Sludge	NO	Not effective for short-term projects; requires intensive construction and set effort; does not address metals
	Chemical	UV/Ozone	YES	Proven technology for organics; will destroy compounds without a waste stream
		Chemical Precipitation	YES	Although inefficient with many startup/shutdowns and creates a large sludge volume mobile treatment units do exist and this treatment does work for metals removal
		Ion Exchange	YES	Mobile treatment units exist; will require bench or pilot studies to treat to low arsenic levels
Disposal	Onsite	Injection Well	NO	Tendency to clog
		Percolation Bed	YES	Is available on site and is currently the alternative to water discharge
	Offsite	Storm Sewer	YES	Will require NPDES permit modifications

DEVELOPMENT AND EVALUATION OF ALTERNATIVES

This section evaluates interim response alternatives that have been developed for the M-1 Settling Basins. The alternatives are designed from one or more feasible technologies introduced in Section 3.0. The alternatives address both the contamination on site and any waste streams generated as part of treatment. These alternatives are then evaluated with respect to:

- Overall protectiveness of human health and the environment
- Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)
- Reduction in mobility, toxicity, or volume
- Short- and long-term effectiveness
- Implementability

Costs associated with the alternatives will be addressed in Section 5.0.

4.1 INTERIM ACTION ALTERNATIVES

Eight alternatives have been developed as interim response actions (IRAs) according to Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), as amended by SARA, 1986, guidance (Environmental Protection Agency 1988). The suite of alternatives includes administrative, containment, treatment, and temporary storage/disposal options. The alternatives are:

Alternative Description

- | | |
|---|---|
| 1 | No action |
| 2 | Monitoring |
| 3 | Institutional controls |
| 4 | Slurry wall with cap |
| 5 | Multilayered cap |
| 6 | In-situ vitrification |
| 7 | Chemical fixation with onsite storage |
| 8 | Chemical fixation with offsite disposal |

The first three alternatives do not involve containment or treatment but are included per EPA guidance document, "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA," Interim Final October 1988.

The next two alternatives represent in-place containment with no treatment. These are considered appropriate since this is an IRA. The contamination would remain in place until such time as the overall site remediation addressed this area.

The next two alternatives represent feasible onsite treatment scenarios. One is an in-situ alternative not requiring excavation, while the other requires excavation and soil/sludge treatment on site.

The final alternative consists of excavation and onsite soil/sludge treatment with final disposal at a fully permitted commercial hazardous waste landfill.

Each alternative is described in the following subsections. These designs are conceptual in nature. The details of the selected alternative will be determined during final design.

4.1.1 Alternative 1 - No Action

This alternative assumes that no action will be taken to contain or treat contaminated soils and sludge at the M-1 Settling Basins. Additional groundwater monitoring would not be required if this alternative is selected.

4.1.2 Alternative 2 - Monitoring

This alternative assumes that the only action taken at the M-1 Settling Basins is additional groundwater monitoring. This monitoring would track the continuing effect, if any, of the M-1 Settling Basins on the alluvial aquifer. In addition, monitoring will be part of Alternatives 3 through 8.

The monitoring consists of quarterly sampling and analysis of groundwater from existing monitoring Well Nos. 01083, 01524, 01503, 01504, and 36193. The water will be analyzed for the following analytes:

- Volatile halogenated organics
- Volatile aromatic organics
- Semivolatile halogenated organics
- Total and dissolved arsenic
- Total and dissolved mercury
- ICP metals
- pH

This information will be included as part of the comprehensive monitoring program at the Rocky Mountain Arsenal (RMA). Analysis of these data will help to evaluate how much the M-1 Settling Basins are actively degrading groundwater quality in the area and will provide information necessary to develop a final response action.

Groundwater sampling will occur on a quarterly basis for this alternative and alternatives 3 through 8.

In addition to groundwater monitoring, an air monitoring program will be designed. The program will monitor ambient air for fugitive dust and organic volatilization. It is assumed that four monitoring stations will be set up on all sides of the site.

The sampling effort will include:

- Dust PM 10, for metals and fugitive particulates
- PUF (polyurethane foam), for pesticides
- Tenax/activated carbon, for volatile organic compounds

Air sampling will be performed during the construction operations period of Alternatives 4 through 8.

4.1.3 Alternative 3 - Institutional Controls

The institutional control alternative consists of constructing a fence around the site. This would entail the construction of approximately 910 lineal feet of chainlink fence with controlled access points (i.e., locked gates).

4.1.4 Alternative 4 - Slurry Wall with Cap

The slurry wall and cap alternative would consist of constructing a slurry wall around the M-1 Settling Basins and a cap covering the area enclosed by the slurry wall. This alternative would enclose the source of contamination and reduce the migration of hazardous constituents. The slurry wall and cap would be designed to contain the contamination source until a final remedy action is selected and implemented.

4.1.4.1 Construction of 360° Slurry Wall

The slurry wall would enclose the three M-1 Settling Basins, as well as the berms surrounding the basins, and provide lateral containment of the contamination source. The enclosed area would be about 300 feet long and 115 feet wide. The size of the enclosed area would be slightly less than one acre. The slurry wall would be about 910 feet long and would penetrate through the upper silty, sandy material into the underlying Denver Formation (approximately 18 feet). For this feasibility study, it is assumed conservatively that the slurry wall would be keyed at a depth of 5 feet into the confining layer. Any excess spoil remaining after slurry wall construction will be placed under the cap.

4.1.4.2 Construction of a Multilayered Cap

The cap would be designed and constructed to cover the entire area enclosed by the slurry wall (about one acre). The cap would consist of, from the base upwards, an 18-inch thick compacted clayey soil layer, a 60-mil-thick high-density polyethylene (HDPE) flexible membrane liner, a synthetic drainage net, a geotextile filter fabric, and a 1-foot protective soil layer. The cap would be sloped from the center to the edge at about 2 or 3 percent to facilitate surface water runoff from the cap. This cover design would reduce infiltration of surface water into the M-1 Settling Basins. Water infiltrating the cover would collect onto the clayey soil/flexible membrane composite layer and would be drained to the outside of the cap by gravity through the synthetic drainage net. The geotextile filter fabric would reduce the risk of the synthetic drainage net being clogged by soil particles from the overlying soil layer. Treatment of the protective soil layer, such as cement or asphalt addition, may reduce erosion potential and maintenance of the cover.

4.1.5 Alternative 5 - Multilayered Cap

This alternative would consist of covering the M-1 Settling Basins with a cap to reduce infiltration of surface water. The extent and design of the cap would be the same as that for the slurry wall and cap alternative described above. The cap would be designed and constructed to cover the M-1 Settling Basins, about one acre.

4.1.6 Alternative 6 - In-situ Vitrification

Contaminated soils and sludge would be vitrified in-situ by introducing sufficient electrical current through the soil to raise the soil temperature to its melting point. The current would be introduced by four electrodes placed in the ground in a square array. A slurry wall will be constructed around the in-situ vitrification (ISV) area. It is assumed that dewatering is unnecessary. The water within the

boundaries of the slurry wall will be vaporized during the ISV and water from the surrounding region will not migrate through the slurry wall. The sequence of activities that would be performed in this alternative consists of the following:

- Construction of a 360° slurry wall
- In-situ vitrification in stages throughout the 1-acre site
- Regrade the site

4.1.6.1 Construction of a 360° Slurry Wall

The slurry wall would be constructed as described in subsection 4.1.4 with the exception that the depth of the slurry wall will only be approximately 15 feet. In this case, the slurry wall is used to provide a temporary barrier to groundwater recharge in the vitrification area.

4.1.6.2 In-situ Vitrification

The vitrification process is initiated by the placement of four electrodes in a square array approximately 18 feet apart to a depth of approximately 7 feet. An offgas collection hood will be installed that will route offgases and steam under negative pressure to the offgas control system housed on site in a trailer. A second trailer will house the electrical switchgear that will condition the 4160-volt power obtained from the site power distribution system and deliver it to the electrodes.

The offgas control system will cool, scrub, and filter the vapors collected from the offgassing melt. Assuming this process drives off the 47 percent water fraction of the sludge, approximately 700,000 gallons of water in the form of steam, with trace contaminants of arsenic and mercury, will be generated. This will be condensed indirectly by using a circulating glycol system. Noncondensed acid gases will be absorbed in a packed scrubber column. As a final step in the air pollution control sequence, the exhaust gases will pass through an activated carbon absorber prior to venting to the atmosphere.

The condensate will have elevated concentrations of arsenic and mercury, as well as an alkaline pH. This will require pH adjustment and precipitation of arsenic and mercury to reduce arsenic and mercury levels to accepted discharge limits. Mercury may be in a recoverable form. Actual wastewater treatment will be determined during pilot testing. Any sludge generated in the wastewater treatment will be added to unvitrified soil/sludge for subsequent vitrification. The treated effluent water will be discharged to the alluvial aquifer through a percolation bed.

The process will vitrify the soil/sludge at a rate of approximately 3 to 5 tons/hour. Once the melt is complete, the system will be dismantled and moved to the next area of the vitrification sequence, leaving the melt to cool. To process the approximately 9,000 yd³ of soil, the operation will take about 5 months.

4.1.6.3 Site Regrading

After the vitrification process is complete, some subsidence will have occurred, approximately 40 to 50 percent of the depth of melting. Imported fill will be brought in from nearby, by using standard earth-moving equipment (e.g., loader, end dump trucks, etc.) as necessary to ensure positive surface drainage away from the vitrified area.

4.1.7 Alternative 7 - Chemical Fixation with Onsite Storage

This alternative would include excavation of approximately 10,800 yd³ (9,000 yd³ plus a 20 percent bulking factor) of sludge and soils by sections or subareas to be treated, mixing of the excavated contaminated soils with one or more fixation agents, testing of the treated portions to ensure treatment effectiveness, and placement of the treated soil in an onsite temporary waste pile. This sequence would be repeated for successive subareas until the entire area to be chemically fixed is treated. Two general types of mixing methods are commonly used for the chemical fixation process: batch mixing on the surface of a workpad, or semicontinuous mixing in cement handling equipment, such as a pug mill. The semicontinuous approach is more likely to be employed for this remediation.

Chemical fixation is based on treatment methods that surround or encapsulate waste components in a stable inorganic matrix. The treatment additives are selected to accomplish one or more of the following results: reduce the mobility of contaminants by reducing the surface area exposed to leaching fluids, reduce the solubility or toxicity by chemically binding the contaminants into a crystal or inorganic lattice, or solidify or otherwise improve the handling properties of the bulk waste.

Typical additives are sodium silicate, portland cement, fly ash, or kiln dust. The resulting material will remain friable even after curing; that is, it will not harden into a concrete mass. The exact composition and volume of fixing agents are not currently known, since these treatment specifics vary somewhat with the vendor, and the vendor has not yet been selected. For the same reason, an exact increase in volume is not known, although it is estimated that bulking factors of between 10 and 20 percent by volume could be expected. A bench-scale treatability test program should be conducted to determine the proper additives and additive ratios.

Chemical fixation is well-suited for the metals contamination at this site. Certain organic contaminants in the surface soil can also be immobilized by chemical fixation.

A storage pad will be constructed for storage of excavated soils prior to chemical fixation. The storage pad will have a clay liner and sump for drainage to minimize contact between contaminated and uncontaminated soil and precipitation. A second pad of similar size will be constructed nearby for storage of treated soils. The pads will be constructed with low permeability liners. Each pad will be surrounded on the perimeter with a containment berm. Contaminated soils will be run through screens to separate large fragments. The screening device will most probably be a slanted vibrating screen or series of screens with a screen size of 1/4 inch. Larger fragments may be crushed prior to fixation. Any uncrushable debris will be collected and cleaned or transported to a hazardous waste disposal facility. After screening and crushing, the soil will be moved into and through the fixation machinery and then to the fixed materials pad. The area required for the equipment would be approximately 2,000 ft². For the purpose of cost and schedule development, it is assumed that excavation and treatment of the contaminated soils will proceed in 500 yd³ per day increments using two units. Soil excavation at the M-1 Settling Basins may require backhoes, loaders, bulldozers, and personal protective equipment.

During operations, confirmation samples from the treated soil stockpile and the excavation limits will be collected for chemical testing, for comparison to leachate and/or cleanup criteria. The fixation contractor will take performance samples of the treated material after mixing and will test for chemical stability. In addition, one sample of every 10 will be tested with the proposed EPA toxicity characteristic leaching procedure (TCLP) test to indicate leachable organic and metal materials.

The chemically fixed soils and sludges will be temporarily stored in an onsite waste pile. This waste pile would be constructed with a clay liner and cap as well as a synthetic liner, leachate monitoring and collection sump, and groundwater monitoring wells. The fixed soils/sludges must pass leachability tests before they are stored in the waste pile.

4.1.7.1 Temporary Waste Pile

A waste pile would be constructed above ground in the vicinity of the M-1 Settling Basins for the temporary storage of the chemically fixed materials. The waste pile would be designed to hold about 11,900 yd³ (9,000 yd³ plus 20 percent for excavation bulking, plus 10 percent for bulking from the fixation process) of contaminated materials. The bottom liner and leachate collection system would consist of, from the base upwards, an 18-inch-thick compacted clayey soil layer, a 60-mil-thick HDPE flexible membrane liner, a synthetic drainage net, and a geotextile filter fabric. The bottom liner would be

sloped at a minimum of 2 percent toward a leachate collection sump. Liquids collecting in the leachate collection sump would be removed. The treated soils would be placed in the waste pile in lifts and compacted to minimize settlement after placement. The first lift of soil in the waste pile would be placed in a manner that would not damage the completed liner system. The total height of the soil in the waste pile would be about 15 feet. Once all the contaminated materials have been placed in the waste pile, a cover would be constructed to close the waste pile. The cover system would consist of, from the base upwards, an 18-inch-thick compacted clayey soil layer, a 60-mil-thick HDPE flexible membrane liner, a synthetic drainage net, a geotextile filter fabric and a 1-foot-thick protective soil layer. Treatment of the protective soil layer, such as cement or asphalt addition, may be used to improve the erosion resistance of the soil and reduce maintenance.

4.1.7.2 Transportation to Temporary Waste Pile

The fixed soil/sludge will be placed on dump trucks and sent to the nearby waste pile described in the previous section. Assuming a chemical fixation rate of 500 yd³ per day, this operation should take approximately 17 days and involve approximately 30 to 35 daily round trips of a 15 yd³ capacity dump truck between the M-1 Settling Basins and the newly constructed waste pile.

4.1.7.3 Site Restoration

After completion of the excavation operation, the site will be regraded. The site will then be revegetated for erosion control.

Site operations for the chemical fixation process with onsite storage are as follows:

- Excavate contaminated soil, dewater if necessary, and transport to storage pad.
- Collect confirmation samples from base of final excavation.
- Screen all debris and solids 1/4-inch or greater in diameter from the soils.
- Crush oversized material to the appropriate size.
- Collect untreatable debris, if present, and store temporarily or haul to a hazardous waste landfill.
- Convey contaminated soils from the storage pad to the fixation processing equipment.

- Add fixation chemicals and water to the soils and mix to uniformity.
- Transfer the fixed soil to the treatment pad for temporary storage and sampling.
- Backfill the basin area with engineered fill.
- Construct waste pile.
- Transport fixed soil to the onsite temporary waste pile.

4.1.8 Alternative 8 - Chemical Fixation with Offsite Disposal

Contaminated soils and sludges can be excavated and disposed of offsite in a hazardous waste landfill. Due to the high water content of the M-1 Settling Basin sludges, this material would need to be chemically fixed before it can be placed in a landfill. The sequence of activities that would be performed in this alternative consists of the following:

- Chemical fixation of soil/sludge
- Transportation to offsite landfill
- Site regrading

4.1.8.1 Chemical Fixation of Soil/Sludge

Soil and sludge from the M-1 Settling Basins would be chemically fixed according to the same procedures described in subsection 4.1.7.

4.1.8.2 Transportation to Offsite Landfill

The dump trucks hauling contaminated soil/sludge will be decontaminated and secured prior to hauling. The soil will be sent to the USPCI hazardous waste landfill near Clive, Utah. Hauling costs per yard of material are cited in Section 5.0. Therefore, the total volume of 11,900 yd³ was used for the cost calculations. Disposal was quoted per ton, so a density of 1.5 tons/yd³ was used to convert volume to weight.

4.1.8.3 Site Regrading

After excavation, the site will be regraded and revegetated as described in subsection 4.1.7.3.

4.2 INTERIM ACTION EVALUATION CRITERIA

The interim action alternatives just presented will be evaluated based on the following criteria:

- Overall protection of human health and the environment
- Conformance with ARARs
- Reduction of mobility, toxicity, or volume
- Short- and long-term effectiveness
- Implementability
- Cost

The IRA objectives identified in paragraphs 22.5 through 22.7 of the Federal Facility Agreement are included in these criteria. The definition and interpretation of these criteria are outlined in this section. Costs are discussed in Section 5.0.

How each alternative addresses each of the evaluation criteria will be presented in greater detail in Section 6.0; however, a summary of alternative evaluation criteria is presented in matrix form in Tables 4-1 and 4-2. (Tables are located at the end of this section.)

4.2.1 Overall Protection of Human Health and the Environment

This criterion assesses whether each alternative provides adequate protection of human health and the environment. Assessment of protection draws upon other evaluation criteria, especially short-term effectiveness and compliance with ARARs and considers whether each alternative poses unacceptable short-term or cross-media impacts.

4.2.2 Conformance with ARARs

One criterion used to evaluate each of the interim action alternatives is compliance with ARARs. Alternatives that meet all ARARs will be preferred because they ensure that interim action will be conducted in a manner that protects human health and the environment.

4.2.3 Reduction of Mobility, Toxicity, or Volume

Reduction of waste mobility, toxicity, or volume reduces the potential of that waste to harm humans or the environment. This evaluation criterion evaluates the process effectiveness to reduce organic and metals concentrations and to reduce waste quantity. Some of the specific issues addressed in the evaluation of this criterion include the following:

- Does the process completely destroy organics?
- Does the process permanently immobilize organics?
- Does the process reduce the mobility of organics?
- Does the process permanently immobilize the metals?
- Does the process reduce the mobility of metals?
- Does the process significantly reduce the toxicity of organics?
- Does the treatment produce a reduction in hazardous waste volume?
- Does the process result in an increase in hazardous waste volume?

4.2.4 Short- and Long-term Effectiveness

The effectiveness of the interim alternatives will be considered in terms of its short- and long-term effectiveness in meeting the remedial action objectives.

Short-term effectiveness examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation period until objectives have been met. Short-term effectiveness has two elements: community protection and worker protection.

Community protection considers any risk that results from implementation of the proposed interim action. Some of the questions that identify potential community risks from a remedial process are:

- If a process failed, what would be the effect on the community?
- Are effective mitigation measures available to reduce community risk if the process fails?
- How will the effects on the community be addressed and mitigated?

Worker protection evaluations during interim response activities consider the potential threats that may be posed to workers and the effectiveness and reliability of protective measures that could be taken. Some considerations for worker protection issues are:

- What are the risks to workers that must be addressed?
- How will the risks to workers be addressed and mitigated?
- What risks remain to the workers that cannot be readily controlled?

Long-term effectiveness examines the effectiveness of each alternative in maintaining protection of human health and the environment after response objectives have been met. This evaluation is divided with two main criteria: magnitude of residual risk and adequacy and reliability of long-term controls to manage that residual risk. Some of the questions addressed in this evaluation are:

- What risk remains, relative to a no-action alternative?
- What type of long-term monitoring is required?
- What difficulties and uncertainties may be associated with long-term operation and maintenance?
- Is there a clear and significant long-term benefit in implementing this alternative now?

4.2.5 Implementability

The implementability criterion addresses the technical and administrative feasibility of an alternative and the availability of various services and materials required for its implementation. Some of the specific issues to be evaluated include the following questions:

- Is the technology generally available and sufficiently demonstrated on a full scale?
- What difficulties or uncertainties are related to implementation; could these lead to schedule delays?
- Are the necessary equipment and specialists available?
- Will more than one vendor be available to provide a competitive bid?
- Are adequate treatment, storage capacity, and disposal services available; can additional capacity/services be developed if necessary?
- What are the monitoring requirements during implementation?

- What effect would this alternative have on implementing a final remedy?
- How long would it take to implement the alternative?

TABLE 4-1
TECHNICAL EVALUATION OF ALTERNATIVES
M-1 SETTLING BASINS
THRESHOLD CRITERIA

Alternative	Interim Response Action	Overall Protectiveness of Human Health and the Environment	Compliance with ARARs
1. No Action		Not protective	There are no location-specific or action-specific ARARs for this alternative, nor would it meet ambient or chemical-specific ARARs
2. Monitoring		Not protective	This alternative will comply with location-specific or action-specific ARARs related to monitoring. Ambient or chemical-specific ARARs would not be met.
3. Institutional Controls	Install fencing	Marginally protective	The institutional controls will comply with location-specific or action-specific ARARs related to access. Ambient or chemical-specific ARARs would not be met.
4. Slurry wall with cap	-Site preparation -Construct slurry wall -Construct cap	Somewhat protective; reduces risk by isolating material from environment; vertical and horizontal migration retarded	This alternative will be designed to comply with ARARs to the maximum extent practicable.
5. Multilayered Cap	-Site preparation -Construct cap	Somewhat protective; reduces risk by isolating material from surface; infiltration barrier limits vertical migration	This alternative will be designed to comply with ARARs to the maximum extent practicable.
6. In-situ Vitrification	-Site preparation -Construct slurry wall -Vitrify solids -Regrade site	Protective; reduces risk by destroying organics and immobilizing remaining metal contaminants	This alternative will be designed to comply with ARARs to the maximum extent practicable.

TABLE 4-1
(Continued)

Alternative	Interim Response Action	Overall Protectiveness of Human Health and the Environment	Compliance with ARARs
7. Chemical Fixation with Onsite Storage	<ul style="list-style-type: none"> -Site preparation -Construct waste pile -Excavate -Dewater (if necessary) -Treat extracted water and discharge to percolation beds (if necessary) -Chemical fixation of both organics and metals -Onsite storage of treated soil in waste pile -Regrade site 	Protective; reduces risk by immobilizing metal and organic contaminants	This alternative will be designed to comply with ARARs to the maximum extent practicable.
8. Chemical Fixation and Offsite Disposal	<ul style="list-style-type: none"> -Site preparation -Excavate -Dewater (if necessary) -Treat extracted water and discharge to percolation bed (if necessary) -Chemical fixation of both organics and metals -Transport to offsite RCRA landfill -Regrade site 	Protective; reduces risk by immobilizing metal and some organic contaminants	This alternative will comply with ARARs to the maximum extent practicable.

(11111CO2-3100) (11/18/89)

TABLE 4-2
TECHNICAL EVALUATION OF ALTERNATIVES
M-1 SETTLING BASINS
EVALUATION CRITERIA

Alternative	Reduction of Toxicity, Mobility or Volume	Short-Term Effectiveness	Long-Term Effectiveness	Implementability	Cost
1. No Action	None	None	None	Easily implemented	Low
2. Monitoring	None	Monitoring can begin immediately; no additional impact on community or environment; sampling personnel may require personal protective equipment	Limited long-term effectiveness; potential indicator of future impact on sensitive receptors; re-evaluation necessary	Easily implemented as part of existing monitoring program	Low
3. Institutional Controls	None	Fence construction can begin immediately; no additional impacts on community or environment; construction personnel may require personal protective equipment	Long-term effectiveness limited; access control must be monitored; re-evaluation necessary	Easily implemented; structural integrity necessary to restrict access	Low

(11111CD2-3100) (11/18/89)

TABLE 4-2 (Continued)

Alternative	Reduction of Toxicity, Mobility or Volume	Short-Term Effectiveness	Long-Term Effectiveness	Implementability	Cost
4. Slurry Wall with Cap	Reduces mobility of contaminants to groundwater	Less than one year implementation; no additional impacts on community or environment; construction personnel may require personal protective equipment; dust control measures may be necessary	Long-term effectiveness limited; monitoring required for possible migration through slurry wall; cap integrity inspection required; re-evaluation necessary	Straightforward construction; confining layer fairly shallow, provides sufficient anchor; several contractors available; destruction of cap necessary for further remediation action	Low
5. Multilayered Cap	Partially reduces mobility of contaminants to groundwater by reducing infiltration	Less than one year implementation; no additional impacts on community or environment; construction personnel may require personal protective equipment; dust control measures may be necessary	Long-term effectiveness limited; monitoring required; cap integrity inspection required; re-evaluation necessary	Straightforward construction; destruction of cap necessary for further remedial action	Low
6. In-Situ Vitrification	Mobility of contaminants is greatly reduced; toxicity and volume are reduced	One year implementation; offgassing must be controlled to minimize risk to workers and community	Expected good long-term effectiveness	Technology has gone through significant testing; offgas treatment must be monitored; operations require significant power	High

(11111CO2-3100) (11/18/89)

TABLE 4-2 (Continued)

Alternative	Reduction of Toxicity, Mobility or Volume	Short-Term Effectiveness	Long-Term Effectiveness	Implementability	Cost
7. Chemical Fixation with Onsite Storage	Mobility of contaminants is greatly reduced; toxicity is reduced; volume increased	Less than one year implementation; dust control measures may be necessary; workers may require personal protective equipment	Expected good long-term effectiveness	Fixation technology well-established; treatability testing required; turnkey contractors available	Medium
8. Chemical Fixation with Offsite Disposal	Mobility of contaminants is greatly reduced; toxicity is reduced; volume increased	Less than one year implementation; dust control measures may be necessary; workers may require personal protective equipment; possible community impact associated with transportation of fixed material	Expected good long-term effectiveness; possible transportation risk	Fixation technology well-established; treatability testing required; turnkey contractors available	High

5.0
ECONOMIC EVALUATION OF ALTERNATIVES

The alternatives developed in Section 4.0 have been evaluated with respect to the threshold criteria of protectiveness of human health and the environment, and compliance with applicable or relevant and appropriate requirements (ARARs). They have also been evaluated with respect to:

- Reduction of mobility, toxicity, or volume
- Short- and long-term effectiveness
- Implementability

This section discusses the costs involved with implementing each alternative. Since the Federal Facility Agreement states that the Interim Response Action (IRA) Decision Document should select the most cost-effective alternative that meets the objective of this IRA, these estimated costs will be a fundamental tool in the decision-making process.

5.1 ECONOMIC ASSUMPTIONS

The cost estimates developed for the evaluated alternatives are intended to be used as comparative tools. These study estimates can be considered to have an accuracy of +50 to -30 percent. These estimates are divided into capital costs and operating and maintenance (O&M) costs. A present worth analysis is also presented to compare alternatives with different expenditure patterns.

Whenever possible, vendor quotes for capital and O&M costs are used. However, several other sources of costs have been utilized. These include generic unit costs, previous similar estimates (modified by site-specific information), and conventional cost estimating guides. All costs that are obtained from these materials will be escalated to third quarter 1989 by using the Chemical Engineering plant cost index.

The following engineering assumptions have been used:

- For the purpose of cost comparisons, a 5-year operating life has been assumed for the IRA. This assumption may be altered by the final Record of Decision (ROD).

- Connections to electricity, natural gas, water, and sewer will be provided by RMA at no additional cost to the project.
- Offsite disposal of hazardous solids will be at the USPCI Grassy Mountain landfill near Clive, Utah. Bulk waste will be shipped off site in trucks.
- An operating rate of 7,000 hours/year will be used for continuous processes utilizing mechanical equipment. This allows for approximately 20 percent downtime for maintenance and repair.
- Engineering, design, construction management, and startup are assumed to be 20 to 50 percent of major purchased equipment (MPE) costs to \$5,000,000; 15 to 20 percent of MPE for equipment costs in the range of \$5,000,000 to \$10,000,000; and 5 to 10 percent of MPE for equipment costs in excess of \$10,000,000.
- A contingency of 20 percent has been applied to all capital and O&M cost estimates.
- Utility costs have been estimated by using the following rates:

Electricity*	\$0.085/kwh
Water	\$3.76/1,000 gallons
Natural gas	\$3.359/1,000 ft ³
Sewer	\$1.50/1,000 gallons

In-situ vitrification was costed at \$0.05/kwh because major user rates may be lower.

- Offsite disposal costs have been estimated by using the following rates:

Transportation	\$120/ton
Disposal	\$140/ton

- O&M costs incurred after the first year have been discounted at 5 percent.
- Treatment operations conducted by a turn-key vendor are considered under O&M costs, regardless of treatment duration.

5.2 ALTERNATIVE COSTING

5.2.1 Alternative 1 - No Action

This alternative assumes that no action will be taken to contain or treat contaminated soil/sludge at the M-1 Settling Basins. This alternative results in no capital or O&M costs; therefore, present worth costs are not included in Table 5-1. (Tables 5-1 through 5-9 are located at the end of this section.)

5.2.2 Alternative 2 - Monitoring

Costing for the monitoring alternative includes groundwater monitoring. For the groundwater monitoring plan, it is intended to only have an operations and maintenance cost. Capital costs have not been included because only existing monitoring wells are to be sampled.

Air monitoring is specific to ambient air and will include monitoring stations in each direction from the M-1 Settling Basin area.

Air monitoring would be performed only during the construction operations period of Alternatives 4 through 8. For details on air monitoring capital and O&M costs, refer to Table 5-2.

5.2.2.1 Capital Cost

No capital cost is associated with groundwater monitoring because it is assumed that only existing monitoring wells will be sampled.

Direct cost for the air monitoring program will include the necessary monitoring equipment and program design. Including the 20 percent contingency, the capital cost for air monitoring is \$62,400. This capital cost will be included in the total for Alternatives 4 through 8.

5.2.2.2 Operations and Maintenance

Groundwater and air monitoring O&M costs include quarterly sampling, analysis, and reporting. The totals for groundwater and air monitoring O&M costs are \$168,000 and \$174,700, respectively. Groundwater monitoring O&M costs are included for Alternatives 2 through 8. Air monitoring O&M costs are included during the construction operations of Alternatives 4 through 8.

5.2.2.3 Present Worth Value

The total present worth value for the monitoring alternative of \$727,000 is the present worth value for the groundwater monitoring O&M cost of \$168,000 over 5 years.

5.2.3 Alternative 3 - Institutional Controls

Cost details for Alternative 3 are presented in Table 5-3. The total capital required for this alternative is \$34,900. Besides the 20 percent contingency, the only major cost items are fencing, at \$9,100 and site preparation, at \$20,000.

5.2.3.1 Operations and Maintenance

No additional operations and maintenance costs have been assumed for Alternative 3. Only the O&M cost for groundwater monitoring is included at \$168,000.

5.2.3.2 Present Worth Value

The total present worth value for Alternative 3 is \$762,000, which is a total of the capital and the present worth value of the O&M cost over 5 years.

5.2.4 Alternative 4 - Slurry Wall with Cap

Cost details for Alternative 4 are presented in Table 5-4 and the capital, O&M, and present worth value are summarized in Table 5-1.

5.2.4.1 Capital Cost

Some of the major cost items for the slurry wall and cap construction are: slurry wall and cap construction, \$273,600 and \$84,300, respectively; and engineering design and supervision, \$94,100. Including the 20 percent contingency, the total capital requirement is \$677,300. Construction activities are assumed to be completed in 1 year.

5.2.4.2 Operations and Maintenance

In the summary table, the groundwater and air monitoring O&M costs from Table 5-2 of \$342,700 has been included for the construction operations period (year 1). During the post-interim action period,

the cost items are groundwater monitoring at \$168,000 and cap maintenance at \$25,000 for a total closure period O&M cost of \$193,000.

5.2.4.3 Present Worth Value

The present worth value for this alternative is \$1,655,000, which is the total of the capital and the present worth value of the operations and post interim action O&M costs.

5.2.5 Alternative 5 - Multilayered Cap

Cost details are presented in Table 5-5 and the present worth value summary is presented in Table 5-1.

5.2.5.1 Capital Cost

Major cost items for the total capital requirement are as follows: cap construction, \$84,300; site preparation, \$50,000; air monitoring capital, \$62,400; and engineering and supervision, \$39,300. The total capital requirement for this alternative is \$283,300, including a 20 percent contingency. The construction period is anticipated to be within 1 year.

5.2.5.2 Operations and Maintenance Cost

Similar to Alternative 4, the operation period cost is \$342,700, and the post-interim action O&M cost is \$193,000.

5.2.5.3 Present Worth Value

The total present worth value for this alternative is \$1,261,000, which is a total of the capital and the present worth value of the two O&M costs over the 5-year period.

5.2.6 Alternative 6 - In-situ Vitrification

Cost details for this alternative are presented in Table 5-6 and summarized in the present worth value Table 5-1.

5.2.6.1 Capital Costs

The total capital requirement of \$470,600 is based on the slurry wall construction, and engineering and supervision. Upon completion of the slurry wall, the in-situ vitrification (ISV) process is to begin and is expected to last less than 1 year (assuming one ISV unit at the site).

5.2.6.2 Operations and Maintenance

Annual O&M costs for in-situ vitrification is based on \$20 per ton for offgas treatment operations and \$400 per ton for electrical charges. Because of the increased power requirement, a lower charge of \$0.05 per kwh was used instead of \$0.085 per kwh.

Total ISV cost is \$8,000,200 for the operations and maintenance. This includes the ISV operation, operations monitoring, and engineering and supervision. The operations period costs occur during year 1. From years 2 to 5, post-interim action monitoring costs of \$168,000 occur, which include ground-water monitoring and reporting.

5.2.6.3 Present Worth Value

The present worth value for the operations and post-interim action period O&M cost is \$8,657,000.

5.2.7 Alternative 7 - Chemical Fixation with Onsite Storage

Cost details for this alternative are presented in Table 5-7, and a present worth summarization is presented in Table 5-1.

5.2.7.1 Capital Cost

The total capital requirement is \$624,100, which is based on the liner construction, air monitoring capital, site preparation costs, and onsite waste pile construction. The liner will contain excavated soils prior to treatment as well as treated soil until testing for the chemical fixation is complete.

5.2.7.2 Annual Operations and Maintenance

The total annual O&M cost of \$1,708,100 includes the chemical fixation process at \$65 yd³, soils handling, sampling, and monitoring. The chemical fixation will be completed within 1 year and is to

occur at a rate of 500 yd³ per day (assuming one unit). Performance sampling is based on one sample per 500 yd³ of soil.

A post-interim action cost of \$193,000 will occur from years 2 to 5 and will include both air and groundwater monitoring as well as cap maintenance on the onsite waste pile.

5.2.7.3 Present Worth Value

The total present worth value is \$2,902,000, which is a total of the capital, the present worth for the operating period (year 1), and the post-interim action period (years 2 through 5).

5.2.8 Alternative 8 - Chemical Fixation with Offsite Disposal

Cost details for this alternative are presented in Table 5-8.

5.2.8.1 Capital Cost

The total capital requirement of \$161,900 is based on air monitoring capital and site preparation, which includes removing the existing structures on the basins, as well as engineering and supervision.

5.2.8.2 Operations and Maintenance

Operations and maintenance costs consist of a first year operations cost of \$8,378,400, and a post-interim action O&M of \$168,000 which will occur during years 2 through 5. First year O&M costs include the chemical fixation process at \$65/yd³, performance sampling and monitoring, transporting 17,800 tons to the USPCI hazardous waste facility in Utah, and engineering and supervision. The chemical fixation will be completed at a rate of 500 yd³ per day (assuming one unit). Performance sampling is based on one sample per 500 yd³ of soil/sludge. Disposal and transportation costs are based on \$140/ton and \$120/ton, respectively.

5.2.8.3 Present Worth Value

A total present worth value of \$8,708,000 is the sum of the capital cost and an operations and post-interim action O&M present worth cost of \$8,546,000.

5.3 SENSITIVITY ANALYSIS

A sensitivity analysis has been performed to determine which alternative will be affected by changes in the design basis presented in Section 2.5. Table 5-9 summarizes this analysis and presents the total present worth value for each alternative per sensitivity parameter. A discussion of each parameter follows.

- Additional Volume of Contaminated Soil: The volume of soil/sludge to be treated was increased by assuming a larger extent of contamination. An extended boundary was added to the known boundaries of the M-1 Settling Basins, making the dimensions of the basins 140 feet by 330 feet, and the contamination was assumed to extend to 10 feet below ground surface. The containment alternatives (Alternatives 4 and 5) were only affected slightly by this change with their total present worth value increasing 3 to 5 percent. Chemical fixation with onsite storage total present worth costs were increased 48 percent. In-situ vitrification and chemical fixation with offsite disposal were most affected by the volume change with total present worth cost increases of 73 percent and 78 percent, respectively.
- Double Unit Treatment Costs: Costs for three of the alternatives are dependent on the unit treatment costs. The unit treatment costs were doubled to evaluate the effect of the unit costs on the total cost for the alternatives. Doubling the unit treatment costs had an effect similar to adding additional volumes of contaminated soil. Total present worth costs for chemical fixation with onsite storage increased 37 percent. Total present worth costs for ISV increased dramatically: 81 percent. Total present-worth costs for chemical fixation with offsite disposal only increased 11 percent because the bulk of the cost for that alternative is because of the transport and disposal of the fixed material.

TABLE 5-1
PRESENT WORTH SUMMARY TABLE
M-1 SETTLING BASINS

Design Basis
Soil Volume = 9,000 (yd3)
Discount Factor = 5 %

ALTERNATIVE	CAPITAL COSTS	ANNUAL O & M OPERATIONS	ANNUAL O & M POST-IRA	PRESENT WORTH ANNUAL O&M Opn & Post-IRA	TOTAL PRESENT WORTH VALUE (Cap. + O&M)
ALT 2 - Monitoring	0	Yrs. 1 - 5 \$168,000	NA	\$727,000	\$727,000
ALT 3 - Institutional Controls	\$35,000	Yrs. 1 - 5 \$168,000	NA	\$727,000	\$762,000
ALT 4 - Slurry Wall and Cap	\$677,000	Yr. 1 \$343,000	Yrs. 2 - 5 \$193,000	\$978,000	\$1,655,000
ALT 5 - Multilayered Cap	\$283,000	Yr. 1 \$343,000	Yrs. 2 - 5 \$193,000	\$978,000	\$1,261,000
ALT 6 - In-situ Vittrification	\$471,000	Yr. 1 \$8,000,000	Yrs. 2 - 5 \$168,000	\$8,186,000	\$8,657,000
ALT 7 - Chemical Fixation with Onsite Storage	\$624,000	Yr. 1 \$1,708,000	Yrs. 2 - 5 \$193,000	\$2,278,000	\$2,902,000
ALT 8 - Chemical Fixation with Offsite Disposal	\$162,000	Yr. 1 \$8,378,000	Yrs. 2 - 5 \$168,000	\$8,546,000	\$8,708,000

TABLE 5-2
 ALTERNATIVE 2-GROUNDWATER AND AIR MONITORING: COST ESTIMATE
 M-1 SETTLING BASINS

ASSUMPTIONS:					
(1)	Groundwater samples at \$5000/sample (includes labor, health and safety at Level B personal protective equipment, and analytical)				
(2)	Quarterly groundwater sampling of 5 wells (20 samples/year)				
(3)	Quarterly groundwater monitoring will continue for the duration of the IRA				
(4)	For air monitoring, assume quarterly sampling of four stations on each side of the site				
(5)	Air monitoring samples include dust/metals, pesticides, and volatile organics				
ITEM	DESCRIPTION	UNIT	UNIT COST	AMOUNT	COST
(A) GROUNDWATER MONITORING:					
CAPITAL COSTS (NONE)					
ANNUAL OPERATIONS AND MAINTENANCE					
(1)	Sampling of Existing Monitoring Wells	ea.	\$5,000	20	\$100,000
(2)	Reporting/ Data Interpretation	ea.	\$10,000	4	\$40,000
Subtotal					\$140,000
(3)	Contingency at 20%				28,000
ANNUAL O&M COST					\$168,000
(B) AIR MONITORING:					
(for construction operations only Alternatives 4 through 8)					
CAPITAL COST					
(1)	DUST PM 10	ea.	\$3,000	4	\$12,000
(2)	PUF	ea.	\$4,000	4	\$16,000
(3)	Sampling Pumps	ea.	\$1,000	4	\$4,000
(4)	Technical Support and Program Design	ea.	\$20,000	1	\$20,000
Subtotal					\$52,000
(5)	Contingency at 20%				\$10,400
TOTAL CAPITAL COST					\$62,400
ANNUAL OPERATIONS AND MAINTENANCE (O&M)					
(1)	DUST / metals sampling	ea.	\$1,000	16	\$16,000
(2)	PUF	ea.	\$300	16	\$4,800
(3)	Volatiles	ea.	\$300	16	\$4,800
(4)	Labor	ea.	\$20,000	4	\$80,000
(5)	Interpretation & Reporting	ea.	\$10,000	4	\$40,000
Subtotal					\$145,600
(6)	Contingency at 20%				29,120
ANNUAL O&M COSTS					\$174,720

TABLE 5-3
 ALTERNATIVE 3 - INSTITUTIONAL CONTROLS: COST ESTIMATE
 M-1 SETTLING BASINS

ASSUMPTIONS:

- (1) Institutional controls costs include groundwater monitoring
- (2) Institutional controls consist of perimeter fencing (910 ft), which assumes a 10 foot boundary around the contaminated area

ITEM	DESCRIPTION	UNIT	UNIT COST	AMOUNT	COST
CAPITAL COST					
(1)	Site Preparation				\$20,000
(2)	Fencing	L.F.	\$10	910	\$9,100

		Subtotal			\$29,100
(3)	Contingency at 20%				\$5,820

	TOTAL CAPITAL COST				\$34,920
ANNUAL OPERATIONS AND MAINTENANCE (years 1-5)					
(1)	Groundwater Monitoring (Item A, Table 5-2)				\$168,000
	ANNUAL O&M COSTS				

TABLE 5-4
 ALTERNATIVE 4 - SLURRY WALL WITH CAP: COST ESTIMATE
 M-1 SETTLING BASINS

ASSUMPTIONS:					
(1)	Site preparation will consist of grading and filling of low-lying areas to control runoff				
(2)	A slurry wall will surround the three M-1 Settling Basins. The length of the slurry wall is estimated to be 910 feet. The depth is assumed to be 25 ft.				
(3)	The multilayered cap design is based on most appropriate protection for an interim action				
(4)	Monitoring costs are detailed in Table 5-2				
ITEM	DESCRIPTION	UNIT	UNIT COST	AMOUNT	COST
CAPITAL COST					
(1)	Air Monitoring Capital (Item B, Table 5-2)				\$62,400
(2)	Site Preparation (includes removal of above-ground equipment)				\$50,000
(3)	Slurry Wall	ft2	\$12	22,800	\$273,600
(4)	Construct cap:				
	Clay	yd3	\$8	2,400	\$19,200
	Flexible membrane	yd2	\$5	4,800	\$25,920
	Synthetic drainage net	yd2	\$3	4,800	\$15,840
	Geotextile	yd2	\$2	4,800	\$10,560
	Protective soil layer	yd3	\$8	1,600	\$12,800
	Cap Cost				\$84,320
	Subtotal				\$470,320
(5)	Engineering and Supervision at 20%				\$94,064
	Subtotal				\$564,384
(6)	Contingency at 20%				\$112,877
	TOTAL CAPITAL COSTS				\$677,261
ANNUAL OPERATIONS AND MAINTENANCE COSTS					
A.	Construction Operations Monitoring (year 1) (Items A and B, Table 5-2)				\$342,720
B.	Post-Interim Action Monitoring (years 2-5)				
(1)	Groundwater Monitoring (Item A, Table 5-2)				\$168,000
(2)	Cap Maintenance				\$25,000
	ANNUAL POST-INTERIM ACTION O&M COSTS				\$193,000

TABLE 5-5
ALTERNATIVE 5 - MULTILAYERED CAP: COST ESTIMATE
M-1 SETTLING BASINS

ASSUMPTIONS:

- (1) Site preparation will consist of grading and filling of low-lying areas to control runoff.
- (2) Cap design is the same as the slurry wall and cap alternative.
- (3) Monitoring costs are detailed in Table 5-2.

ITEM	DESCRIPTION	UNIT	UNIT COST	AMOUNT	COST
CAPITAL COST					
(1)	Air Monitoring Capital (Item B, Table 5-2)				\$62,400
(2)	Site Preparation (includes removal of above-ground equipment)				\$50,000
(3)	Construct Cap:				
	Clay	yd3	\$8	2,400	\$19,200
	Flexible Membrane	yd2	\$5	4,800	\$25,920
	Synthetic Drainage Net	yd2	\$3	4,800	\$15,840
	Geotextile	yd2	\$2	4,800	\$10,560
	Protective Soil Layer	yd3	\$8	1,600	\$12,800

	Cap Cost				\$84,320

		Subtotal			\$196,720
(4)	Engineering and Supervision at 20%				\$39,344

		Subtotal			\$236,064
(5)	Contingency at 20%				\$47,213

	TOTAL CAPITAL COST				\$283,277
ANNUAL OPERATIONS AND MAINTENANCE COST					
A.	Construction Operations Monitoring (year 1) (Items A and B, Table 5-2)				\$342,720
B.	Post-Interim Action Monitoring (years 2-5)				
(1)	Groundwater Monitoring (Item A, Table 5-2)				\$168,000
(2)	Cap Maintenance				\$25,000

	ANNUAL POST-INTERIM ACTION O&M COSTS				\$193,000

TABLE 5-6
ALTERNATIVE 6 - IN-SITU VITRIFICATION: COST ESTIMATE
M-1 SETTLING BASINS

ASSUMPTIONS:

- (1) Slurry wall constructed to 15 ft to reduce potential groundwater recharge in the vitrification area
- (2) There will be no dewatering within the slurry wall
- (3) Vitrification cost includes \$400/ton for electricity and \$20/ton for offgas treatment. Assume treatment rate of 6 tons/hr (144 tons per day) for a project life of 105 days (assume 1 year)
- (4) Soil volume = 9,000 yd³ at 1.35 ton/yd³

ITEM	DESCRIPTION	UNIT	UNIT COST	AMOUNT	COST
CAPITAL COST					
(1)	Air Monitoring Capital (Item B, Table 5-2)				\$62,400
(2)	Site Preparation (includes removal of above-ground equipment)				\$50,000
(3)	Slurry Wall	ft ²	\$12	13,700	\$164,400
(4)	Site Restoration Includes: Backfill, grading and replanting				\$50,000
	Subtotal				\$326,800
(5)	Engineering and Supervision at 20%				\$65,360
	Subtotal				\$392,160
(6)	Contingency at 20%				\$78,432
	TOTAL CAPITAL COST				\$470,592
ANNUAL OPERATIONS AND MAINTENANCE (year 1)					
(1)	Construction Operations Monitoring (Items A and B, Table 5-2)				\$342,720
(2)	Mobilization/Demobilization				\$110,000
(3)	Vitrify Solids				
	soil vitrification	ton	\$400	12,150	\$4,860,000
	offgas treatment	ton	\$20	12,150	\$243,000
	Vitrification				\$5,555,720
(4)	Engineering and Supervision at 20%				\$1,111,144
	Subtotal				\$6,666,864
(5)	Contingency at 20%				\$1,333,373
	ANNUAL O&M COSTS				\$8,000,237
ANNUAL POST-INTERIM ACTION O&M COSTS (years 2-5)					
	Groundwater Monitoring (Item A, Table 5-2)				\$168,000

TABLE 5-7
ALTERNATIVE 7 - CHEMICAL FIXATION WITH ONSITE STORAGE: COST ESTIMATE
M-1 SETTLING BASINS

ASSUMPTIONS:

- (1) Onsite above-ground waste pile construction and filling operations will be performed within one year
- (2) Waste pile bottom liner system includes leachate collection system
- (3) Waste pile cover consists of a multilayered system
- (4) Waste pile volume assumes a 20% bulking factor from excavation plus 10% bulking from chemical fixation
- (5) Soils will be excavated and stored on a temporary pad that will also contain the chemical fixing process equipment
- (6) Treatment will be conducted by a turnkey contractor within the first year

ITEM	DESCRIPTION	UNIT	UNIT COST	AMOUNT	COST
CAPITAL COST					
(1)	Air Monitoring Capital (Item B, Table 5-2)				\$62,400
(2)	Site Preparation (includes removal of above-ground equipment)				\$50,000
(3)	Construct Waste Pile				
	Waste Pile Construction				
	Area Preparation	yd3	\$3	2,500	\$7,500
	Clayey Soil Liner	yd3	\$8	2,500	\$20,000
	Flexible Membrane Liner	yd2	\$5	4,900	\$26,460
	Synthetic Drainage Net	yd2	\$3	4,900	\$15,680
	Geotextile Filter Fabric	yd2	\$2	4,900	\$10,780
	Cover Construction				
	Clayey Soil Liner	yd3	\$8	2,600	\$20,800
	Flexible Membrane Liner	yd2	\$5	5,200	\$28,080
	Synthetic Drainage Net	yd2	\$3	5,200	\$16,640
	Geotextile Filter Fabric	yd2	\$2	5,200	\$11,440
	Protective Soil Layer	yd3	\$8	1,700	\$13,600

	Waste Pile Costs				\$170,980
(4)	Liner Construction (for temporary storage and treatment facility)				\$100,000
(5)	Site Restoration				\$50,000

	Subtotal				\$433,380
(6)	Engineering and Supervision at 20%				\$86,676

	Subtotal				\$520,056
(7)	Contingency at 20%				\$104,011

	TOTAL CAPITAL COST				\$624,067

TABLE 5-7 (Continued)

ANNUAL OPERATIONS AND MAINTENANCE (year 1)				
(1)	Construction Operations Monitoring (Items A and B, Table 5-2)			\$342,720
(2)	Soils Handling (backfilling included)	yd3	\$12	10,800
(3)	Chemically Fix Soils	yd3	\$65	10,800
(4)	Performance Sampling and Monitoring	yd3	\$500	24

			Subtotal	\$1,186,200
(5)	Engineering and Supervision at 20%			\$237,240

			Subtotal	\$1,423,440
(6)	Contingency at 20%			\$284,688

	ANNUAL O&M COSTS			\$1,708,128
ANNUAL POST-INTERIM ACTION O&M COST (years 2-5)				
(1)	Groundwater Monitoring (Item A, Table 5-2)			\$168,000
(2)	Cap Maintenance			\$25,000

	ANNUAL POST-INTERIM ACTION O&M COSTS			\$193,000

TABLE 5-8
ALTERNATIVE 8 - CHEMICAL FIXATION WITH OFFSITE DISPOSAL: COST ESTIMATE
M-1 SETTLING BASINS

ASSUMPTIONS:

- (1) Soils will be excavated and stored on a temporary pad that will also contain the chemical fixing process equipment
- (2) Treatment will be conducted by a turnkey contractor within the first year
- (3) Soils will be transported to the USPCI facility in Grassy Mountain, Utah at a cost of \$120/ton transportation and \$140/ton disposal
- (4) Soil amount = 6,400 yd³ + 20% excavation bulking + 10% chemical fixation bulking; assume 1.5 tons/yd³ for fixed materials

ITEM	DESCRIPTION	UNIT	UNIT COST	AMOUNT	COST
CAPITAL COST					
1)	Air Monitoring Capital (Item B, Table 5-2)				\$62,400
2)	Site Preparation (includes removal of above-ground equipment)				\$50,000

		Subtotal			\$112,400
3)	Engineering and Supervision at 20%				\$22,480

		Subtotal			\$134,880
4)	Contingency at 20%				\$26,976

	TOTAL CAPITAL COST				\$161,856
ANNUAL OPERATIONS AND MAINTENANCE (year 1)					
(1)	Construction Operations Monitoring (Items A and B, Table 5-2)				\$342,720
(2)	Soils Handling (backfilling included)	yd ³	\$12	10,800	\$129,600
(3)	Chemically Fix Soils	yd ³	\$65	10,800	\$702,000
(4)	Performance Sampling and Monitoring	yd ³	\$500	22	\$10,800
(5)	Transport to Offsite Facility	ton	\$120	17,820	\$2,138,400
(6)	Offsite Landfill Disposal Fee	ton	\$140	17,820	\$2,494,800

		Subtotal			\$5,818,320
(7)	Engineering and Supervision at 20%				\$1,163,664

		Subtotal			\$6,981,984
(8)	Contingency at 20%				\$1,396,397

	ANNUAL O&M COSTS				\$8,378,381
ANNUAL POST-INTERIM ACTION O&M COSTS (years 2-5)					
	Groundwater Monitoring (Item A, Table 5-2)				\$168,000

TABLE 5-9
SENSITIVITY ANALYSIS
M-1 SETTLING BASINS

Sensitivity Parameter	Alt 4 Slurry Wall Cap	Alt 5 Multilayered Cap	Alt 6 In-situ Vitrification	Alt 7 Chem Fix Onsite Storage	Alt 8 Chem Fix Offsite Disposal
Design Basis	\$1,655,000	\$1,261,000	\$8,657,000	\$2,902,000	\$8,708,000
Additional Soil Volume to be Addressed	\$1,738,000	\$1,297,000	\$14,983,000	\$4,298,000	\$15,467,000
Double Unit Cost for Treatment	\$1,655,000	\$1,261,000	\$15,656,000	\$3,970,000	\$9,671,000

Note: Alternatives 1, 2, and 3 are not included in this table because changes in contaminated soil/sludge volume and unit treatment costs do not affect these alternatives.

6.0
CONCLUSIONS

This alternative assessment document has summarized the history and extent of contamination at the M-1 Settling Basins. This information was used to develop a basis by which technologies were formulated into eight alternatives to address the contaminated soil and sludge at the site.

This section initiates the decision process by ranking the alternatives and classifying them as preferred, marginally preferred, or not preferred. Preferred and marginally preferred alternatives are then evaluated further based on the evaluation criteria described in Section 4.2.

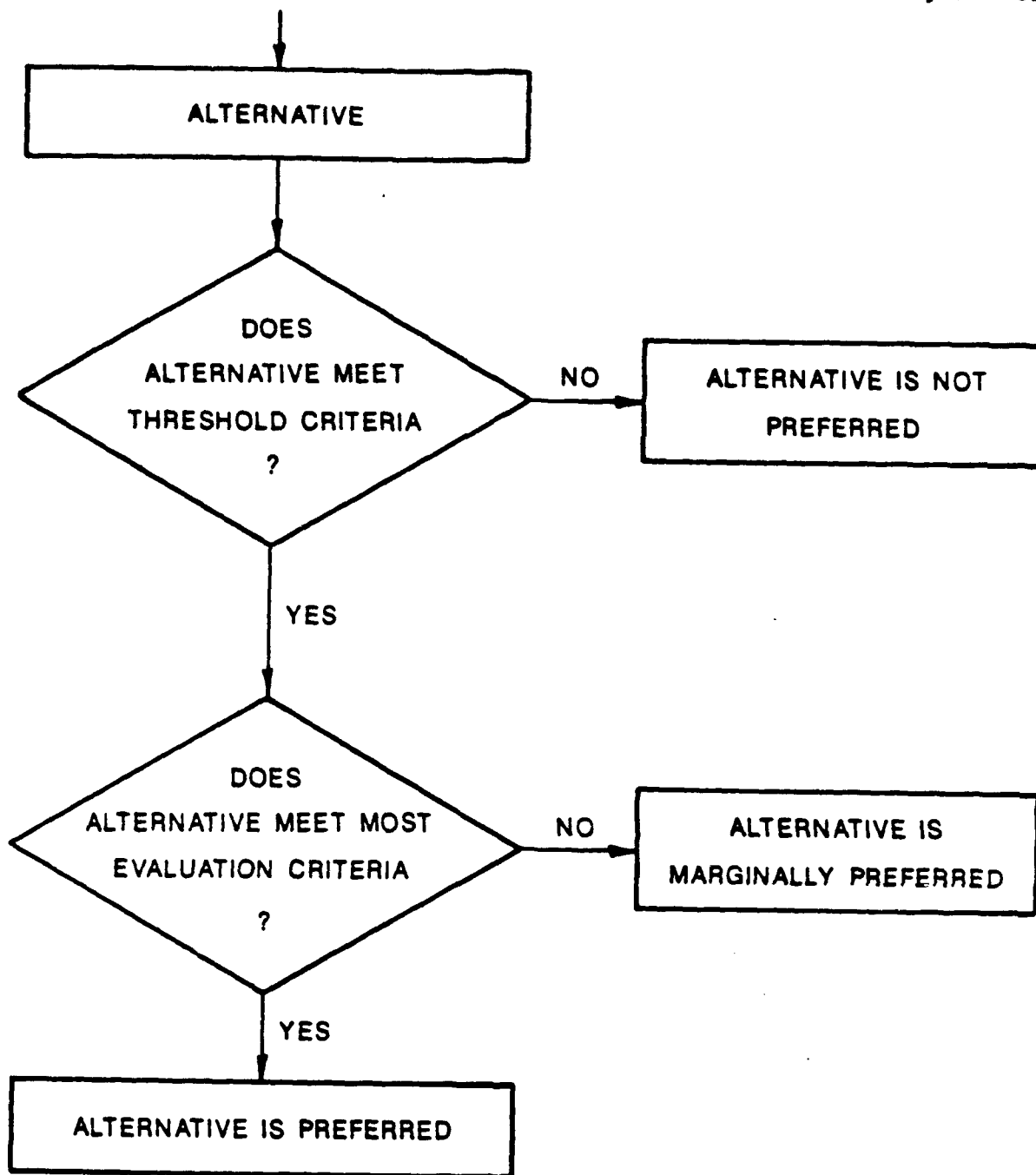
6.1 ALTERNATIVE SCREENING

The eight alternatives were ranked using the decision logic shown in Figure 6-1. The alternatives have been classified as one of the following:

- Preferred: Preferred alternatives meet the threshold criteria listed in Table 4-1 and meet most of the evaluation criteria listed in Table 4-2. Preferred alternatives will be considered further.
- Marginally preferred: Marginally preferred alternatives meet the threshold criteria listed in Table 4-1 to some degree and meet some of the evaluation criteria listed in Table 4-2. Marginally preferred alternatives will be considered further.
- Not preferred: Alternatives that are not preferred either do not meet the threshold criteria of Table 4-1 or meet few of the evaluation criteria of Table 4-2. These alternatives will not be considered further.

The eight alternatives are classified in Table 6-1. There are two preferred alternatives:

- Alternative 6 - In-situ vitrification
- Alternative 7 - Chemical fixation with onsite storage



THRESHOLD CRITERIA: OVERALL PROTECTION OF HUMAN HEALTH
AND THE ENVIRONMENT
COMPLIANCE WITH ARARS

EVALUATION CRITERIA: REDUCTION OF TOXICITY, MOBILITY AND VOLUME
SHORT-TERM EFFECTIVENESS
LONG-TERM EFFECTIVENESS
IMPLEMENTABILITY
COST

Job No. : 22238

Prepared by: K.A.S.

Date: 9/4/89

Figure 6-1 IRA ALTERNATIVE
RANKING

**TABLE 6-1
ALTERNATIVE CLASSIFICATION**

Alternative	Classification	Comments
1. No Action	Not Preferred	Not protective; no reduction in mobility, toxicity, and volume; no short- or long-term effectiveness
2. Monitoring	Not Preferred	Not protective; no reduction in mobility, toxicity, and volume; no long-term effectiveness
3. Institutional Controls	Not Preferred	Not protective; no reduction in mobility, toxicity, and volume; no long-term effectiveness
4. Slurry Wall with Cap	Marginally Preferred	Somewhat protective; reduces mobility, does not reduce contaminant toxicity or volume; good short-term effectiveness; poor long-term effectiveness
5. Multilayered Cap	Marginally Preferred	Marginally protective; partially reduces mobility, does not reduce contaminant toxicity and volume; good short-term effectiveness; poor long-term effectiveness
6. In-situ Vitrification	Preferred	Protective; reduces mobility, toxicity, and volume; good short- and long-term effectiveness; high cost
7. Chemical Fixation with Onsite Storage	Preferred	Protective; reduces mobility and toxicity, increases volume; good long-term effectiveness; some short-term effects possible; treatability testing required
8. Chemical Fixation with Offsite Disposal	Marginally Preferred	Protective; reduces mobility and toxicity, increases volume; good long-term effectiveness, but potential short-term effects possible; treatability testing required; high cost

These alternatives are protective of human health and environment and can be designed to meet ARARs.

There are three marginally preferred alternatives:

- Alternative 4 - Slurry wall with cap
- Alternative 5 - Multilayered cap
- Alternative 8 - Chemical fixation with offsite disposal

Alternatives 4 and 5 are somewhat to moderately protective of human health and the environment. Alternative 8 is considered marginally preferred rather than preferred because it is extremely expensive for an IRA.

There are three alternatives that are not preferred:

- Alternative 1 - No action
- Alternative 2 - Monitoring
- Alternative 3 - Institutional controls

Alternatives 1, 2, and 3 are not protective of human health and the environment and will not be considered further.

The preferred and marginally preferred alternatives will be evaluated and screened in greater detail in the following section.

6.2 ALTERNATIVE EVALUATION

Alternatives have been evaluated against the following criteria:

- Reduction of contaminant mobility, toxicity, or volume
- Short-term effectiveness, including community protection and worker protection
- Long-term effectiveness
- Implementability
- Cost

Tables 6-2 through 6-7 (located at the end of this section) provide details of the evaluation. All alternatives can be implemented in less than 1 year. A summary of the evaluation for each alternative follows.

6.2.1 Alternative 4 - Slurry Wall with Cap

This alternative reduces the vertical and horizontal migration of contaminants, although the toxicity and volume of contaminants are not reduced.

This alternative has good short-term effectiveness. Short-term effectiveness is evaluated based on the effect of the alternative on the community as well as workers at the site during implementation. Impacts on the community during implementation are minimal. Risk to workers during construction can be addressed by using common personal protection and site safety-hazard prevention techniques.

Long-term effectiveness of this alternative is somewhat limited because the alternative is based on a containment technology. Containment does reduce the effects of the source of groundwater contamination, but it does not actually remediate the source. The effectiveness of this alternative as a source mitigation measure would need to be re-evaluated periodically.

This alternative is based on demonstrated technology which can be easily implemented by a number of contractors, although above-ground structures and underground utilities would need to be relocated.

6.2.2 Alternative 5 - Multilayered Cap

This alternative reduces the vertical migration of contaminants, although the horizontal migration, toxicity, and volume of contaminants are not reduced.

This alternative has good short-term effectiveness. Short-term effectiveness is evaluated based on the effect of the alternative on the community as well as workers at the site during implementation. Impacts on the community during implementation are minimal. Risk to workers during construction can be addressed by using common personal protection and site safety-hazard prevention techniques.

Long-term effectiveness of this alternative is considerably limited because the alternative is based on a partial containment technology. Containment does partially reduce the effects of the source of

groundwater contamination, but it does not actually remediate the source. The effectiveness of this alternative as a source mitigation measure would need to be re-evaluated periodically.

This alternative is based on demonstrated technology that can be easily implemented by a number of contractors, although above-ground structures would need to be relocated.

6.2.3 Alternative 6 - In-situ Vitrification

This alternative destroys the organic contaminants, thereby reducing the toxicity of the material, and also, either permanently immobilizes or recovers the metals. The process also reduces waste volume.

This alternative has good short-term effectiveness. Short-term effectiveness is evaluated based on the effect of the alternative on the community as well as workers at the site during implementation. Impacts on the community during implementation are minimal. Possible air emission impacts can be controlled through redundancy of the system design. Risks to workers during implementation can be addressed by using common personal protection and site safety-hazard prevention techniques.

In-situ vitrification has good long-term effectiveness. Risk is substantially reduced by the destruction of the organics and the immobilization or recovery of the metals.

This process has been effectively demonstrated on an engineering scale by the vendor. One concern during the implementation would be that any above-ground structures and underground utilities would need to be relocated.

6.2.4 Alternative 7 - Chemical Fixation with Onsite Storage

This alternative permanently immobilizes the contaminants, although the toxicity is not reduced and the volume of the material is increased.

This alternative has fairly good short-term effectiveness. The only community impact may be air emissions generated during excavation and fixation; however, these can be controlled by shutting down the operation if ambient air and wind monitoring indicate a possible threat. Any risks to workers during implementation can be addressed by using common personal protection and site safety-hazard prevention techniques.

The long-term effectiveness of this alternative is good because the contaminants are permanently immobilized. However, the onsite waste pile would require long-term monitoring and inspection, and relocation of the fixed materials may be necessary depending on future land use.

No full-scale demonstration of this technology on the type of waste material in the M-1 Settling Basins has been reported.

6.2.5 Alternative 8 - Chemical Fixation with Offsite Disposal

This alternative permanently immobilizes the contaminants, although the toxicity is not reduced and the volume of the material is increased.

This alternative has fairly good short-term effectiveness. The major community impact may be air emissions generated during excavation and fixation; however, these can be controlled by shutting down the operation if ambient air and wind monitoring indicate a possible threat. Some risk may be associated with transporting the chemically fixed materials to the offsite disposal facility. Any risks to workers during implementation can be addressed by using common personal protection and site safety-hazard prevention techniques.

The long-term effectiveness of this alternative is good because the contaminants are permanently immobilized.

No full-scale demonstration of this technology on the type of waste material in the M-1 Settling Basins has been reported.

6.3 CONCLUSIONS

Alternative 6, In-situ vitrification, is the preferred alternative. In general, a treatment alternative is preferable to a containment alternative at this site because the source volume is known, the waste characteristics are well-defined, there are high concentrations of contaminants, and because the source is obviously and actively contaminating groundwater. The advantages of in-situ vitrification are that the metals are either immobilized or recovered and that any organic contaminants are destroyed, thereby reducing the toxicity of the material.

Although the containment alternatives are less costly, the treatment costs during any subsequent final remediation would increase due to the increased volume of material that would then include the containment construction materials. Chemical fixation with onsite storage is a less expensive treatment technology, but again the chemically fixed materials, as well as the landfill construction materials, may need to be moved during the final remedy. Chemical fixation with offsite disposal is as costly as the in-situ vitrification, but it does not have the advantage of actually destroying the organic contaminants and could result in some short-term impacts during initial excavation activities.

TABLE 6-2
REDUCTION OF MOBILITY, TOXICITY, OR VOLUME EVALUATION

Subcriteria	Alternative 4- Slurry Wall with Cap	Alternative 5- Multilayered Cap	Alternative 6- In-situ Vitrification	Alternative 7- Chemical Fixation with Onsite Storage	Alternative 8- Chemical Fixation with Offsite Disposal
Does the process completely destroy organics?	No	No	Yes	No	No
Does the process permanently immobilize organics?	No	No	N/A	Yes	Yes
Does the process reduce mobility of organics?	Yes	Yes	N/A	Yes	Yes
Does the process permanently immobilize metals?	No	No	Yes	Yes	Yes
Does the process reduce the mobility of metals?	Yes	Yes	N/A	N/A	N/A
Does the process significantly reduce the toxicity of organics?	No	No	Yes	No	No
Does the treatment produce a reduction in volume	No	No	Yes	No	No

(11111C02-3100) (11/18/89) (RMA)

TABLE 6-2 (Continued)

Subcriteria	Alternative 4- Slurry Wall with Cap	Alternative 5- Multilayered Cap	Alternative 6- In-situ Vitrification	Alternative 7- Chemical Fixation with Onsite Storage	Alternative 8- Chemical Fixation with Offsite Disposal
Does the process result in an in- crease in volume?	Possibly. Slurry wall and cap construction materials may re- quire subsequent remediation	Possibly. Cap construction materials may require subseq- uent remedia- tion	No	Yes	Yes

N/A - Not applicable

TABLE 6-3
SHORT-TERM EFFECTIVENESS EVALUATION: COMMUNITY PROTECTION

Subcriteria	Alternative 4- Slurry Wall with Cap	Alternative 5- Multilayered Cap	Alternative 6- In-situ Vitrification	Alternative 7- Chemical Fixation with Onsite Storage	Alternative 8- Chemical Fixation with Offsite Disposal
If the process fails, what would be the effect on the community?	Possible release of volatile organics to atmosphere during slurry wall installation	None	Possible air emissions	Possible air emissions during excavation and fixation	Possible air emissions during excavation and fixation; some risks associated with transportation
Are effective mitigation measures available to reduce community risk if the process fails?	Yes	N/A	Yes	Yes	Yes
How will the effects on the community be addressed and mitigated?	Ambient air and wind monitoring would shut down operations if a threat exists	N/A	Redundancy in emission control equipment. Ambient air and wind monitoring would shut down operations if a threat exists	Ambient air and wind monitoring would shut down operations if a threat exists	Ambient air and wind monitoring would shut down operations if a threat exists

N/A - Not applicable

(11111CO3-3100) (11/18/89) (RMA)

TABLE 6-4
SHORT-TERM EFFECTIVENESS EVALUATION: WORKER PROTECTION

Subcriteria	Alternative 4- Slurry Wall with Cap	Alternative 5- Multilayered Cap	Alternative 6- In-situ Vitrification	Alternative 7- Chemical Fixation with Onsite Storage	Alternative 8- Chemical Fixation with Offsite Disposal
What are the risks to the workers that must be addressed?	Volatile organics inhalation; excavation safety hazards	Volatile organics inhalation; construction safety hazards	Volatile organics inhalation; construction safety hazards	Volatile organics inhalation; excavation safety hazards	Volatile organics inhalation; excavation safety hazards
How will the risks to the workers be addressed and mitigated?	Proper personal protective equipment	Proper personal protective equipment	Proper personal protective equipment	Proper personal protective equipment; sloping of excavation sidewalls	Proper personal protective equipment; sloping of excavation sidewalls
What risks remain to the workers that cannot be readily controlled?	General construction site safety hazards	General construction site safety hazards	General construction site safety hazards	General construction site safety hazards	General construction site safety hazards; transportation risk

(11111CO2-3100) (11/18/89) (RMA)

TABLE 6-5
LONG-TERM EFFECTIVENESS EVALUATION

Subcriteria	Alternative 4- Slurry Wall with Cap	Alternative 5- Multilayered Cap	Alternative 6- In-situ Vitrification	Alternative 7- Chemical Fixation with Onsite Storage	Alternative 8- Chemical Fixation with Offsite Disposal
What risk remains, relative to a no-action alternative?	Risk is somewhat reduced by physical barrier and reduction of vertical and horizontal contaminant migration	Risk is marginally reduced by physical barrier and reduction of vertical contaminant migration	Risk is substantially reduced by destroying organic contaminants and immobilizing metals	Risk is reduced by immobilizing contaminants	Risk is reduced by immobilizing contaminants
What type of long-term monitoring is required?	Groundwater monitoring; cap inspection"	Groundwater monitoring; cap inspection	Groundwater monitoring	Groundwater monitoring; waste pile cap inspection, liner detection, and leachate detection and analysis	Groundwater monitoring
What difficulties and uncertainties may be associated with long-term operation and maintenance?	Some uncertainty as to adequate amount of data collection during groundwater monitoring; long-term cap integrity uncertain	Some uncertainty as to adequate amount of data collection during groundwater monitoring; long-term cap integrity uncertain	Some uncertainty as to adequate amount of data collection during groundwater monitoring	Some uncertainty as to adequate amount of data collection during groundwater monitoring; long-term landfill integrity uncertain	Some uncertainty as to adequate amount of data collection during groundwater monitoring

TABLE 6-5 (Continued)

Subcriteria	Alternative 4- Slurry Wall with Cap	Alternative 5- Multilayered Cap	Alternative 6- In-situ Vitrification	Alternative 7- Chemical Fixation with Onsite Storage	Alternative 8- Chemical Fixation with Offsite Disposal
Is there a clear and significant benefit in implementing this alternative now?	Yes, vertical and horizontal migration would be reduced	No. Only verti- cal migration would be reduced	Yes, any organics would be destroyed and inorganics would either be recovered in offgas treatment or permanently immobilized	Yes, mobility of contaminants would be greatly reduced	Yes, mobility of contaminants would be greatly reduced

(11111C02-3100) (11/18/89) (RMA)

TABLE 6-6
IMPLEMENTABILITY EVALUATION

Subcriteria	Alternative 4- Slurry Wall with Cap	Alternative 5- Multilayered Cap	Alternative 6- In-situ Vitriification	Alternative 7- Chemical Fixation with Onsite Storage	Alternative 8- Chemical Fixation with Offsite Disposal
Is the technology generally available and sufficiently demonstrated on a full scale?	Yes	Yes	Technology has been demonstrated on an engineering scale	No full-scale demonstration on this type of material has been done	No full-scale demonstration on this type of material has been done
What difficulties or uncertainties are related to implementation; could these lead to schedule delays?	Above-ground structures and underground utilities need to be relocated	Above-ground structures need to be relocated	Some uncertainties associated with scale-up; above-ground structures and underground utilities need to be relocated; presence of groundwater may slow operation	Above-ground structures and underground utilities need to be re-located; some uncertainty as to the effectiveness of the technology on this waste	Above-ground structures and underground utilities need to be relocated; some uncertainty as to the effectiveness of the technology on this waste
Are the necessary equipment and specialists available?	Yes	Yes	Yes	Yes	Yes
Will more than one vendor be available to provide a competitive bid?	Yes	Yes	No	Yes	Yes

(11111C02-3100) (11/18/89) (RMA)

TABLE 6-6 (Continued)

Subcriteria	Alternative 4- Slurry Wall with Cap	Alternative 5- Multilayered Cap	Alternative 6- In-situ Vitrification	Alternative 7- Chemical Fixation with Onsite Storage	Alternative 8- Chemical Fixation with Offsite Disposal
Are adequate treatment storage capacity, and disposal services available; can additional capacity services be developed if necessary?	N/A	N/A	N/A	A waste pile would need to be constructed	N/A
What are the monitoring requirements during implementation?	Ambient air and groundwater monitoring	Ambient air and groundwater monitoring	Ambient air and groundwater monitoring; off-gas monitoring	Ambient air and groundwater monitoring	Ambient air and groundwater monitoring
What effect would this alternative have on implementing a final remedy?	Slurry wall and cap construction materials may require subsequent remediation	Cap construction materials may require sub-sequent remediation	None	Fixed waste materials and waste pile construction materials may require relocation	None
How long would it take to implement the alternative?	Less than one year	Less than one year	Less than one year	Less than one year	Less than one year

(11111C02-3100) (11/18/89) (RMA)

- Brochine. Undated. "Procestechnologie, Heidenij Uitroering."
- Considine, Douglas M. 1974. *Chemical and Process Technology Encyclopedia*.
- Costa, J.E., Bilodeau, S.W. 1982. *Geology of Denver, Colorado, United States of America. "Bulletin of the Association of Engineering Geologist," Vol. XIX, No. 3.*
- DeVoto, R.H. 1968. *Quaternary History of the Rocky Mountain Arsenal and Environs, Adams County, Colorado: Quarterly of the Colorado School of Mines.*
- Ebasco Services, Inc. 1987. *Final Technical Plan, Program for Army Spill Sites, Phase I. Volume I. Version 3.2, Task No. 24. November 1987. RIC 88286RO6.*
- Ebasco Services, Inc. 1988. *Final Phase I Data Presentation Report, Army Spill Sites, South Plants Manufacturing Complex, Task No. 24, Version 3.2. September 1988. RIC 88286R10.*
- Ebasco Services, Inc. 1989a. *Proposed Final Remedial Investigation Report, Volume VIII, South Plants Study Area, Section 1.0. June 1989. RIC 89166RO4.*
- Ebasco Services, Inc. 1989b. *Draft Final Remedial Investigation Report, Central Study Area. Version 2.1. March 1989. RIC 89166RO6.*
- Environmental Protection Agency. 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA. EPA/540/6-89-004.*
- Environmental Protection Agency. 1989. *SITE, Solidification/Stabilization Process. March 1989. EPA/540/M5/89/001.*
- Environmental Science and Engineering, Inc. 1988. *Sump 1727 Interim Response Action Alternatives Assessment, Final Report, Version 3.2. July 1988. RIC 88243RO1.*
- Evans, D.M. 1966. *The Denver Area Earthquakes and the Rocky Mountain Arsenal Disposal Well. "The Mountain Geologist," Vol. 3, No. 1.*
- Hansen, W.R., Crosby, E.J. 1982. *"Environmental Geology of the Front Range Urban Corridor and Vicinity, Colorado." U.S. Geological Survey Professional Paper 1230.*
- Haun, J.D., Kent, H.C. 1965. *Geologic History of the Rocky Mountain Region. "Bulletin of the American Association of Petroleum Geologists," Vol. 49, No. 11.*
- Lindvall, Robert M. 1980. *Geologic Map of the Sable Quadrangle, Adams and Denver Counties, Colorado.*
- May, J.H. 1982. *Regional Groundwater Study of Rocky Mountain Arsenal, Denver, Colorado: U.S. Army Engineer Waterways Experiment Station.*
- Romero, J.C. 1976. *Groundwater Resources of the Bedrock Aquifers of the Denver Basin, Colorado: Denver, Colorado Department of Natural Resources, Division of Water Resources.*
- Scott, G.R. 1960. *Subdivision of the Quaternary Alluvium East of the Front Range near Denver, Colorado: Geologic Society of America Bulletin, Vol. 71, No. 10.*

Woodward-Clyde Consultants

Sonneberg, S.A. 1982. The Lanyard Field, A Structural-Stratigraphic Trap, Denver Basin, Colorado: "The Mountain Geologist." Vol. 19, No. 3.

Stollar, R.L. & Associates, Comprehensive Monitoring Program: Annual Groundwater Report, V. 1

Weimer, R.J. 1973. April. A Guide to Uppermost Cretaceous Stratigraphy, Central Front Range, Colorado: Deltaic Sedimentation, Growth Faulting, and Early Laramide Crustal Movement. "The Mountain Geologist," Vol. 10, No. 3.

Woodward-Clyde Consultants. 1989. Results of Field and Laboratory Investigations Conducted to Evaluate Interim Response Actions for Other Contamination Sources.

Zimpro, Inc. 1987. Personal Communication with J. Meidl and A. Withelm, Rothschild, WI.

APPENDIX A
COMMENTS AND RESPONSES

Shell Oil Company



One Shell Plaza
P O Box 4320
Houston, Texas 77210

October 10, 1989

Office of the Program Manager for Rocky Mountain Arsenal
ATTN: AMXRM-PM: Mr. Donald L. Campbell
Rocky Mountain Arsenal, Bldg 111
Commerce City, CO 80022-2180

Dear Mr. Campbell:

SUBJECT: SHELL'S COMMENTS ON ALTERNATIVE ASSESSMENT FOR M-1
SETTLING BASINS

Enclosed are Shell Oil Company's comments on the Draft Final Alternative Assessment of Response Actions, M-1 Settling Basins, September 1989, Version 2.0. Shell's ARAR comments are being sent under separate cover today.

Sincerely,

A handwritten signature in cursive script, appearing to read "R. D. Lundahl".

R. D. Lundahl
Manager Technical
Denver Site Project

/ajg

Enclosure

cc: (w/enclosures)
Mr. Connally Mears
Air and Waste Management Division
U.S. Environmental Protection Agency, Region VIII
One Denver Place
999 18th Street, Suite 500
Denver, CO 80202-2405

Mr. Mike Gaydosh
Air and Waste Management Division
U.S. Environmental Protection Agency, Region VIII
999 18th Street, Suite 500
Denver, CO 80202-2405

Mr. Jeff Edson
Hazardous Materials and Waste Management Division
Colorado Department of Health
4210 East 11th Avenue
Denver, CO 80020

Mr. David L. Shelton, Director
hazardous Materials and Waste Management Division
Colorado Department of Health
4210 East 11th Avenue
Denver, CO 80020

Victoria Peters, Esq.
Office of Attorney General
CERCLA Litigation Section
One Civic Center
1560 Broadway, Suite 250
Denver, CO 80202

Lt. Col. Scott P. Isaacson
Environmental Litigation Branch
601 Pennsylvania Avenue N.W.
Room 6123
Washington, D.C. 20004

Mr. Robert L. Duprey
Director, Air and Waste Management Division
U.S. Environmental Protection Agency, Region VIII
One Denver Place
999 18th Street, Suite 1300
Denver, CO 80202-2405

T. Kicera
Agency for Toxic Substance Disease Control
8AT-TS
999 18th Street, Suite 500
Denver, CO 80202-2405

Dr. Peter Gober
U.S. Fish and Wildlife Service
Rocky Mountain Arsenal, Bldg. 111
Commerce City, CO 80022-2180

U.S. Department of the Interior
ATTN: Region Environmental Officer
Mr. Richard P. Kruegar
Denver Federal Center, Bldg. 67, Room 840
P.O. Box 25007
Denver, CO 80225-0007

Director, Office of Health Assessments
ATSDR

Mr. Mark Bashor
1600 Clifton Road
Atlanta, CA 30333

Mr. Bruce M. Huenefeld
Interim Response Division
Office of the Program Manager for Rocky Mountain Arsenal
ATTN: AMXRM-IA
Commerce City, CO 80022-2180

**RESPONSE TO SHELL OIL COMPANY'S COMMENTS ON DRAFT FINAL ALTERNATIVE
ASSESSMENT OF INTERIM RESPONSE ACTIONS, M-1 SETTLING BASINS
NOVEMBER 1989**

GENERAL COMMENTS

Shell Oil's major concerns with this Draft Final Alternatives Assessment are as follows and are discussed in further detail under Specific Comments.

Comment 1: Although this assessment asserts that the M-1 Settling Basins "appear to be" a direct source of arsenic contamination of the groundwater, the "preliminary analytical results" which evidently form the basis for this statement are not provided. Meaningful comment on the site assessment by other Organizations and the State is therefore not possible.

Response: In order to meet the mandated schedule, it was necessary to issue the Alternative Assessment of Interim Response Actions for Other Contamination Sources, M-1 Settling Basins to the Organizations and the State for comment prior to the validation and distribution of the laboratory data from samples collected during the field investigation for this Task Order. While the Army appreciates that this approach may have caused some confusion, it does not impact the process. The Army views the "hot spot" investigations as a three-step process. The first step is a field investigation to evaluate whether the M-1 Settling Basins (or other "hot spots") are a source of groundwater contamination. If a "hot spot" is evaluated as being a source of groundwater contamination, as is the case with the M-1 Settling Basins, an alternative assessment is developed for the purpose of evaluating the various technologies and alternatives which may be appropriate for mitigating any potential releases of contaminants from the M-1 Settling Basins. The third step, based on the assessment of Step 2, is to select an interim action alternative and document that decision.

Once a "hot spot" has been evaluated as being a source of groundwater contamination, Step 2 can be initiated. What the other Organizations and the State are being asked to comment on in this document are the alternatives considered for mitigating potential releases of contaminants from the M-1 Settling Basins. The Army believes that meaningful comments can be made on the alternatives presented even though all data had not been validated and presented.

Comment 2: This assessment does not adhere to the Final Task Plan for Other Contamination Sources Interim Response Actions. Specifically, the assessment proceeds to screening and evaluation of IRA alternatives notwithstanding that it fails to address the first decision node of the Decision Flow Chart (Figure 1-1 of the Technical Plan) for "Hot Spot" IRA's; i.e., Is the site an active primary source (of groundwater contamination)? The site is not characterized because of inadequate data. Pursuant to the Decision Flow Chart, the appropriate action for this site therefore should be monitoring (meaning additional site characterization).

Response: The Army did in fact address the first decision node on the referenced figure by stating "The M-1 Settling Basins appear to be a direct source of arsenic contamination to the groundwater." Therefore, the answer to the first question "Is the site an active primary source?" is "Yes." Adequate data to characterize the site were collected and analyzed. At the time of publication, the data had not been fully validated and so were not included. The validated data are included in this final report and in the Field and Laboratory Investigation Report (WCC 1989).

Comment 3: The Decision Flow Chart presented in this assessment (Figure 1-2) is an altered version of the Flow Chart actually agreed to by the Organizations and the State at the June 7, 1989 Other Contamination Sources Subcommittee meeting. Specifically, Data Inadequate should be on the NO leg of the first decision node, not on the YES node. The version agreed to is shown in Figure 1-1 of the final Technical Plan. This alteration appears to have misdirected this

assessment into an unnecessary extensive screening and evaluation of alternative remedial actions even though the site has not been characterized by field data as an active primary source.

Response: The Decision Flow Chart was modified to provide for a slightly more conservative path through the decision process in recognition of the fact that not all data were validated at the time of publication. The point is now moot, however, since the validated data provide a "Yes" answer to the "active primary source" question. Shell's assertion that the alteration in the flow chart leads to "an unnecessary extensive screening" is incorrect. The Army's approach was both schedule-sensitive and cost-effective. It was based on (1) a high level of confidence in the preliminary data, (2) the desire to eliminate costly and unneeded additional documents simply because of delays in data validation, and (3) the need to maintain an aggressive schedule. The flow chart appears as originally agreed to in this final assessment.

Comment 4: This assessment gives insufficient weight to objectives and guidelines set forth in the Federal Facility Agreement and the Technical Program Plan (FY88-FY92) for IRA's, emphasizing instead the guidelines of CERCLA Section 120. Consequently, the assessment is biased toward treatment alternatives which are better suited for consideration in the Final Remedy rather than as interim response actions. The intention that IRA's provide early response actions utilizing cost-effective, proven technologies to mitigate the threat of releases is subordinated to the longer term remediation goals of CERCLA. Many of the treatment alternatives which survived screening in this assessment would require considerable time for either or both development and demonstrating effectiveness on the RMA or implementing the treatment technology. They also pose the risk of not being consistent with the Final Remedy.

Response: The Army agrees that it may be desirable to give increased weight to Federal Facility Agreement and Technical Program Plan guidance. The effects of this change in weight will be most evident in Section 6.0, which presents a preliminary ranking of alternatives. It is emphasized that this is an alternative assessment, not a decision document, and it is necessary to assess all options, including no action, institutional controls, containment, and treatment in order to evaluate which alternative best meets the objectives of the IRA. A revised ranking is presented in this final assessment.

The treatment technologies presented as alternatives in this assessment have undergone feasibility testing. Consistency with the final remedy is one of the criteria evaluated in Section 6.2.

Comment 5: Groundwater treatment is not considered in this assessment except as it may be used in dewatering operations. The logic for this is not very clear in the text but may be based on the premise that groundwater remediation is beyond the scope of this IRA. While this is a correct premise, rejection of groundwater treatment as a technology option ignores the fact that groundwater interception and treatment is an effective containment strategy with favorable aspects with respect to the IRA objective and guidelines as set forth in the FFA and TPP. In fact, this strategy is widely employed on the RMA. All existing and pending groundwater intercept/treatment systems on the RMA are justified on the basis of containment, not remediation of groundwater.

Response: The Army acknowledges that many IRAs employ groundwater interception and treatment as a containment strategy. However, this was considered during alternative development and rejected at the M-1 Settling Basins on the basis of the maintenance associated with an extraction and treatment system, and of the sludge handling problems that would occur because of the high arsenic concentrations in the groundwater at this site. Other alternatives are available that can mitigate releases from the M-1 Settling Basins without significant long-term operations and maintenance, and without generating secondary waste streams which are difficult to handle.

Comment 6: The focus of this assessment is blurred because the text confuses objectives with remedial action strategies and CERCLA guidelines and criteria (Section 3.1). Consequently, in Shell's opinion, a large amount of the work performed in this assessment is misguided and unnecessary. The single objective of this IRA is provided in the Technical Program Plan, Section 3.3.2.7, to wit: Mitigate the threat of releases from selected "hot spot" (M-1 Settling Basins) contamination sources. This objective, which was agreed to by the Organizations, should be the focus of both alternative development and evaluation.

Response: The text has been changed to be consistent with the wording of the Technical Program Plan, Section 3.3.2.7. However, this does not affect the subsequent technology screening and alternative evaluation, since the major objective of the proposed interim action has always been to mitigate the threat of release from the source.

Comment 7: Because of the foregoing, the screened list of alternatives in Section 6.0 Conclusions includes treatment alternatives, specifically 6, 7 and 8, which seem inappropriate for an interim response action at this site and excludes two containment strategies which seem appropriate, specifically groundwater interception/treatment and source collection with temporary storage in a waste pile.

Response: The Army developed and evaluated a broad range of alternatives, some of which are treatment alternatives. One of the important evaluation criteria is implementability. Alternatives which cannot be implemented within a time frame consistent with an interim response action do not survive the screening process. Any treatment alternative which can be implemented in a timely manner should not be considered "inappropriate" simply because this is an interim response action.

The Army considered two containment alternatives in its assessment. Groundwater interception and treatment was not considered since it includes an ongoing operating and maintenance element with continued waste disposal requirements.

The major existing environmental impact of the M-1 sludge material is degradation of alluvial groundwater quality. Based on the site history and previous investigations, this sludge material could potentially contain lewisite or Army agent degradation products. The Army sees no benefit in the excavation of this material only to store it, untreated, on site. There are less expensive containment options (slurry wall and cap) and treatment options that are better suited to this particular site.

SPECIFIC COMMENTS

Comment 1: Page 1-1, first paragraph.

"The M-1 Settling Basins appear to be a direct source of arsenic contamination to the groundwater. This evaluation is discussed in Section 2.2.2."

No data are presented in Section 2.2.2 or elsewhere in this report which support this statement even though this conclusion is used as a basis for concluding that assessment of interim response action alternatives is necessary.

Response: See response to Shell's General Comment No. 1.

Comment 2: Page 1-1, last paragraph.

"An interim response action, as defined by this document, refers to any possible interim action..."

The scope and objectives of Interim Response Actions implemented for remediation of the RMA are defined in the Federal Facility Agreement (FFA) and the Technical Program Plan (TPP) and are the result of considerable discussions between the Organizations and the State and have been agreed to by the Organizations. It is therefore improper to conduct this Alternative Assessment on the basis of how an Interim Response Action is "defined in this (Alternative Assessment) document", unless the definition agreed to by the Organizations and the State is used. As discussed in General Comments, this assessment is misdirected due in part to a failure in recognizing the objectives and guidelines for IRA's as set forth in the FFA and the TPP.

The phrase "as amended by the Superfund Amendments and Reauthorization Act of 1986" should be added before "(CERCLA)".

Response: The IRA Alternative Assessment has been conducted in accordance with the Federal Facility Agreement and the Technical Program Plan. The text has been changed to better reflect this.

Comment 3: Page 1-4, second paragraph.

"The type of action taken, either long-term monitoring or interim treatment..."

The choices are not limited to monitoring or treatment. The objective of the Remediation of Other Contamination Sources IRA is stated clearly in the Army's Technical Program Plan at 3.3.2.7: "Mitigate the threat of releases from selected "hot spot" contamination sources." Consistent with this objective, the intent of RMA IRA's is to prevent the worsening of problems, i.e., increase in cost of, or time required for, the Final Remedy. It is not to remediate sites, although remediation to acceptable levels may result. Considering emphasis on timely implementation of IRA's, this objective will usually be best met by a containment or isolation action. In some cases, treatment may facilitate containment or isolation. The focus however should be on preventing the spread of contamination, not on remediation.

Response: It is agreed that the objective of the IRA is to mitigate the threat of releases from the site. However, it is appropriate to evaluate a range of alternatives in order to meet this objective, not excluding treatment alternatives. The text has been changed.

Comment 4: Page 1-4, third paragraph.

"If the answers to the questions on the decision flow chart are inconclusive, a conservative approach will be taken. For example, if a clear risk to human or biota receptors has not been shown, it will be assumed that some risk exists."

There are several serious misrepresentations in this statement which in part cause this assessment to be misdirected.

First, the issue involved here is not one of conservatism of approach to an interim response action, but is simply a matter of the data being inadequate to perform an assessment. To proceed with a specific action with inadequate data risks wasting valuable resources on work which may not protect the environment or human health, even in fact do harm, and may not be consistent with the Final Remedy.

Second, it was not agreed that if data are inconclusive or inadequate, a conservative approach would be taken. The agreement reached by the Organizations and the State in the June 7, 1989 Subcommittee meeting was that inadequate data would trigger the monitoring/maintenance action. Monitoring/maintenance may include further site investigation. The Decision Flow Chart in this assessment (Figure 1-2) is an altered version of the flow chart agreed to and which appears as Figure 1-1 in the Final Task Plan for Remediation of Other Contaminant Sources Interim Response Action. Specifically, the Data Inadequate decision path has been moved from

the NO to the YES pathway. Figure 1-2 of this assessment document should be replaced by the agreed to version. Data presented on this site are inadequate to assess the question of whether the M-1 Settling Basins are an active primary source of groundwater contamination. Accordingly, before proceeding with screening and evaluation of technology alternatives, further site investigation should be conducted.

Response: See response to Shell's General Comment No. 3.

Comment 5: Page 1-4, fourth paragraph.

"...there may be some benefit in performing an IRA now. ...The benefit in performing any of these actions will be discussed in the IRA Decision Document."

If the reason for considering an interim response action for this site is a possible long term benefit to cost or timing of RMA remediation, how can a meaningful discussion of alternatives be achieved if these possible benefits are not addressed? Clearly, achievement of a long term benefit in cost or timing should be a primary consideration and criterion in the development and evaluation of alternatives.

Response: Agreed. These issues are discussed in greater detail in Section 6.2 of the final alternatives assessment.

Comment 6: Page 2-2, third paragraph.

The structures presently on and near the M-1 Settling Basins were used in the manufacture of bicycloheptadiene (BCH) which is not an insecticide. BCH is an intermediate in the manufacture of aldrin and dieldrin. BCH operations terminated in 1974 and these structures were not used thereafter.

Response: *The text has been changed.*

Comment 7: Page 2-3, last paragraph.

Aquifer tests in the alluvial and Denver Formation aquifers have shown the hydraulic conductivities to vary much more than the ranges listed in this paragraph.

Response: The text has been changed.

Comment 8: Page 2-4, second paragraph.

In Table 2-2, the concentrations of several organic contaminants in groundwater are significantly higher in downgradient wells than in upgradient wells. These contaminants include bicycloheptadiene, chloroform, chlorophenylmethyl sulfone, dicyclopentadiene, dieldrin, and diisopropylmethyl phosphonate. These data indicate that the M-1 Basins could be a possible source of these contaminants. Did the spring 1989 sampling program include only arsenic and mercury as analytes? The two new wells (01083 and 36193) are favorably located for providing upgradient/downgradient water quality data. Analysis of a comprehensive analyte suite for these wells would enhance the site investigation.

Response: The Army agrees that the M-1 Settling Basins could be a source of the above-mentioned contaminants. The 1989 sampling program did include only arsenic and mercury as analytes. However, additional site characterization would not have affected the decision that the M-1 Settling Basins are a source of groundwater contamination. Also, the alternatives assessment would not have been affected by additional site characterization because the possible presence of organic contaminants was considered during the screening of alternatives.

Comment 9: Page 2-4, last sentence.

Well No. "10183" should be "01083."

Response: The text has been changed.

Comment 10: Page 2-5, first paragraph.

The physical form of the mercury contamination should be indicated, i.e., mercury salts (solid) or elemental mercury (liquid), since the physical state is an important criterion in the evaluation of the remediation technologies.

Response: The analytical methods used during site characterization reported mercury concentration in the sludge without regard to its physical/chemical form. The site history relates the fact that spent mercuric chloride catalyst was disposed of in the basins. Whether or not mercury still exists in this form is unknown. The chemical state of the mercury could affect the effectiveness of chemical fixation. Treatability testing of that technology would be required.

Comment 11: Page 2-5, second paragraph.

The interpretation that high concentrations of arsenic are being transported by attachment to soil particles moving with the groundwater may be in error. Basing this interpretation on the difference in the concentration of arsenic between filtered and unfiltered groundwater samples from Well 01503 and 01504 is not advisable because of the proximity of the wells to the M-1 Basins. Monitoring well sampling procedures can mobilize soil particles near the wellbore; thus, the presence of sediment in groundwater samples may not be representative of normal aquifer conditions. Because these wells could be located within a few feet of the sludge, the high arsenic concentrations in the unfiltered samples from these wells do not necessarily indicate that significant arsenic migration by this mechanism is occurring.

How far downgradient do high concentrations of arsenic persist?

Response: Agreed. The interpretation of the difference between filtered and unfiltered sample arsenic analyses has been revised based on results of the 1989 field investigation. Please see the revised text in Section 2.2.2.

Arsenic concentrations were found as far north as the Lime Settling Basins. At that point, arsenic contamination from the Lime Settling Basins occurs. It is difficult to determine what portion of the arsenic contamination downgradient of the Lime Settling Basins is actually attributable to the M-1 Settling Basins.

Comment 12: Page 2-5, third paragraph.

How do you reconcile the observations that in previous sampling very little of the arsenic was in soluble form and in 1989 sampling almost all arsenic was in soluble form? If standardized sampling procedures were used and background aquifer conditions (Eh and pH) were relatively stable, the total/dissolved ratio should not have changed so drastically.

If the "high concentration of arsenic immediately downgradient of the M-1 Settling Basins" was obtained from Well 01503 or 01504, it is questionable that significant migration of arsenic has occurred. These wells are located near the basins and could be within a few feet of the sludge. Without providing the spring 1989 data, the distribution of arsenic is unknown and the conclusion that the "M-1 Settling Basins are a direct source of groundwater contamination" is also questionable. The pre-1989 water quality data in Table 2-2 also do not support the Army's

conclusion because no upgradient data were included. Further investigation is needed to decide whether this site is a primary active source of groundwater contamination.

Response: We cannot reconcile the conflicting observations. Different sample preparation or preservation methods may have been used.

The spring 1989 data clearly show arsenic concentrations to be higher downgradient of the M-1 Settling Basins than upgradient. Wells 36001 and 36193 were also sampled, which are further downgradient of the M-1 Settling Basins. These data have been included in Table 2-2 of the final alternatives assessment and are discussed in detail in the Field and Laboratory Investigation Report (WCC 1989).

Comment 13: Page 2-5, third paragraph.

This paragraph states that "preliminary" analytical results from groundwater sampling conducted in Spring 1989 indicates that the M-1 Settling Basins are a direct source of groundwater contamination. However, these data are apparently not presented in this report. If these data were considered sufficiently reliable to trigger the extensive engineering work performed in this assessment, why can't they be published in this assessment document? In accordance with the Decision Flow Chart, pending a determination on whether or not the M-1 Settling Basins are an active primary source, development of response alternatives should not have been begun.

An adequate site assessment is an essential predicate for the development and screening of technology alternatives. Data on, and interpretation of, contaminant concentrations in the basins, as well as in up- and down-gradient groundwater, are a requirement. The other Organizations and the State cannot provide meaningful comment when primary data which is said to "indicate" that this site is an active primary source are not shown.

The profile of groundwater contamination in Table 2-2, coupled with the history of these basins, strongly suggest that other sources contribute to groundwater contamination in the area around these basins. The close proximity of the basins to the old chemical sewer line (Figure 1-1) suggests one likely source.

Response: See responses to Shell's General Comments Nos. 1, 2, and 3. The validated data is presented in the final alternative assessment.

Comment 14: Page 2-6, 2.3 Contaminant Fate and Transport

This Section, which is very general and theoretical (with respect to this specific site), could serve as an introduction to an assessment of the site data to address the question of whether or not the M-1 Settling Basins are an active primary source. However, it does not constitute a site assessment.

The last sentence of the first paragraph states: "This section presents the fate and transport of both the organics and metals detected in these field investigations." This should be revised to state that possible mechanisms for fate and transport at this site are discussed.

Contaminants whose source(s) are upgradient of the basins should not be included in this discussion. They are beyond the scope of this IRA.

The brevity and simplicity of statements in this Section raise questions as to its value to this assessment. For example, the whole discussion (2.3.1.1.2) of volatilization of semivolatile chlorinated hydrocarbons is:

"The semivolatile chlorinated hydrocarbons are somewhat volatile (Table 2-3) and could be lost by volatilization into the atmosphere. These compounds are more volatile than the pesticides."

Response: This section has been revised.

Comment 15: Page 2-6, Section 2.3.1 - Fate of the Organics.

We suggest that the discussion in this section be divided into two sections: (1) a discussion of the fate and transport of the contaminants in soils, and (2) a discussion of the fate and transport of the contaminants in groundwater. Also, at some point in this section, the Army should provide pH data for the soils in the M-1 Settling Basins.

Response: The text has been changed. According to the South Plants Study Area report, the pH of soils in the South Plants Area ranges from 6.3 to 9.0. The site history of the M-1 Settling Basins and the pH levels found during groundwater sampling seem to imply that the soils in the immediate vicinity of the M-1 Settling Basins are most likely alkaline.

Comment 16: Page 2-6, Section 2.3.1.1 - Volatilization.

The volatilization process is incorrectly stated for the following reason:

The volatilization of organic compounds from soils is dependent on several factors, including soil temperature and moisture content, vapor pressure, solubility of the compound in water, compound concentration, the ability of two or more contaminants to form azeotropic mixtures, air flow over the soil surface, humidity, sorptive and diffusion characteristics of the soil, and bulk properties of the soil such as organic matter content, porosity, density, clay content and clay mineralogy. All of these factors affect the distribution of a compound between soil, soil water, soil air, and the atmosphere.

Response: The text has been changed.

Comment 17: Page 2-6, fourth paragraph.

Aldrin and dieldrin were not detected in the M-1 Basin sludge (Table 2-1); therefore, the M-1 Basins are probably not a source of these compounds.

Response: The text has been changed to focus on compounds that were consistently detectable in the M-1 sludge and over burden soil

Comment 18: Page 2-7, fourth paragraph.

A reference should be provided for the statement that chloroform has a half-life of 3,500 years.

Response: The statement has been deleted.

Comment 19: Page 2-8, first paragraph.

Aldrin and dieldrin are not the only compounds present for which plant uptake is expected. Cadmium is readily adsorbed by plants. The arsenic concentration in plants varies between 0.01 and 1.0 ppm (Brown, "Hazardous Waste Land Treatment," at 242). Moreover, very little if any aldrin and/or dieldrin may be adsorbed by native plants if the oil content of the plants is low.

Response: Discussion of aldrin and dieldrin has been deleted from the revised text. However, with the small amount of plant life at the site, plant uptake is probably insignificant.

Comment 20: Page 2-8, second paragraph.

Biodegradation takes place with some species of fungi as well as some bacteria.

Response: Agreed. The text has been changed.

Comment 21: Page 2-8, Sections 2.3.1.6.1 through 2.3.1.6.3.

The rate of biodegradation of organic compounds in nature is a function of several factors including the structure of the compound, soil temperature, and soil physiochemistry. The biodegradation of benzene in soils is rapid, but the biodegradation of carbon tetrachloride is slow. The use of biodegradation to destroy a contaminant requires a specific organism to attack a specific compound under suitable environmental conditions.

Response: Reference to South Plants alluvial groundwater contaminants has been deleted in the revised text.

Comment 22: Page 2-10, first paragraph.

Through the text, "adsorption" is incorrectly referred to as "absorption."

Why are only lignite seams in the Denver Formation a hindrance to migration of organics? Wouldn't claystones in the Denver Formation have a similar effect?

Response: The text has been changed.

Comment 23: Page 2-10, fourth paragraph.

Evapotranspiration is the dominant fate of precipitation at RMA. Infiltration is normally minor except during intense storms or where it is enhanced such as by drainage ditches, catch basins, etc.

Response: The text has been changed. However, some infiltration is still expected to occur given the nature of the sandy soils at the site.

Comment 24: Page 2-11, second paragraph.

Evapotranspiration is the dominant fate of precipitation at RMA; however, infiltration is the major pathway from a contaminant transport perspective.

Response: Agreed.

Comment 25: Page 2-11, third paragraph.

Aldrin and dieldrin transport with rainwater to the groundwater is possible, but based on the adsorption coefficients this transport mechanism is not very likely.

Response: Reference to aldrin and dieldrin has been eliminated in the revised text.

Comment 26: Page 2-11, fourth paragraph.

At the low concentrations of hexachlorocyclopentadiene detected, it is not likely that its high density affects its downward migration rate.

Response: Agreed. The text has been changed.

Comment 27: Page 2-12, first paragraph.

Soluble organics can migrate with the groundwater, but it should be pointed out that each compound has different retardation factors. Migration will vary widely for this list of compounds.

Response: Agreed. The text has been changed.

Comment 28: Page 2-12, first paragraph, second sentence.

"(G)roundwater gradient" should be "groundwater migration rate."

Response: The text has been changed.

Comment 29: Page 2-12, second paragraph.

"Bicycloheptadiene and dicycloheptadiene are highly volatile (Table 2-3)."

It is not accurate to describe these compounds as highly volatile.

Response: The text has been changed.

Comment 30: Page 2-12, third paragraph.

High solubility and low sorption are much more important than volatility for movement of chemicals down to and through the Denver Formation.

Response: Agreed. The text has been changed.

Comment 31: Page 2-12, Section 2.3.3.

While in general metals remain predominantly in the soils over time, a particular metal may be oxidized or reduced to a different species. For example, arsenic in soils is converted to arsenates except under highly reducing conditions. Arsenate ions are readily sorbed by hydrous oxides of iron and aluminum and thus leaching of arsenate is slow. Arsenic behaves much like phosphorus in soils in that adsorption of arsenic increases as iron oxide content increases. All of the arsenic halides are covalent compounds that hydrolyze in the presence of water. EPA, "Ambient Water Quality Criteria Document: Arsenic" at 3.

Moreover, the National Research Council of Canada reports that the half-life of arsenic trioxide in soils is 6.5 years, but the half-life of lead arsenate is 16 years. The loss of arsenic from the soils over time must be accounted for by the transport of arsenic to other media.

In aerobic water, inorganic arsenic (III) is slowly oxidized to arsenic (V) at neutral pH, but the reaction proceeds measurably in strongly acidic or alkaline solutions. EPA, "Ambient Water Quality Criteria Document: Arsenic."

A similar discussion could be presented for each of the metals present in the M-1 basins, but the point of the matter is this: the fate and transport of metals in this paragraph and section 2.3.4 are addressed in a superficial fashion.

Response: The text has been changed.

Comment 32: Page 2-13, Section 2.3.4.

The term "nonsoluble" should be replaced with "insoluble." This paragraph is over generalized to the point of being erroneous. For example, some metal oxides, such as chromium (VI) oxide, mercuric oxide, and arsenic pentoxide, are soluble in water. Humic metal complexes have conditional stability constants that vary with pH, and follow the Irving-Williams series. In general, the stabilities of aquatic humic complexes follow this order for the metals present at this site:



See E. M. Thurman, "Organic Geochemistry of Natural Waters," at 415. Given the conditions at this site, some of the metals may not be sorbed on the surface of humic material (if humic material is present).

Response: The text has been changed.

Comment 33: Page 2-14, first sentence.

Soil erosion is more related to soil type and condition, vegetative cover, and precipitation intensity than it is to annual precipitation.

Response: Agreed. The text has been changed.

Comment 34: Page 2-14, first full paragraph.

Total Threshold Limit Concentration (TTLC) is a criterion used only in California and is therefore not appropriate for use at RMA.

Response: Agreed. The text has been changed to eliminate this reference.

Comment 35: Page 2-14, second paragraph.

Infiltration to groundwater is not a very significant pathway at RMA without some mechanism of recharge enhancement.

Response: Intermittent infiltration is a possible pathway at Rocky Mountain Arsenal.

Comment 36: Page 2-14, paragraph under 2.4.

"With the available knowledge of the nature and distribution of chemical contaminants at the site as well as the fate and transport of these chemicals in the environment, a survey of applicable or relevant and appropriate regulations (ARARs) is necessary."

This statement is misleading if it is meant to imply that the prior Sections have established that the M-1 Settling Basins are an active primary source of groundwater contamination. Since this has not been done, it is suggested that this statement be deleted or modified. There has been practically no knowledge in the form of data presented in these Sections.

Response: See response to Shell's General Comment No. 2.

Comment 37: Page 2-15, third paragraph.

"No aquifer dewatering and subsequent treatment will be necessary for the purpose of this interim response action."

Please explain the rationale for this statement and why this assumption is necessary. Groundwater interception/treatment is a cost-effective containment strategy which has been selected as the alternate of choice in several other IRA's and all three boundary control systems on the RMA.

Response: See response to Shell's General Comment No. 5.

Comment 38: Table 2-2, Summary of Contaminants in Groundwater.

The only data presentation in this assessment bearing on possible migration of contaminants from the M-1 Basins to groundwater is this table. The simple listing of concentration ranges upgradient and downgradient is an inadequate basis for attempting to interpret whether contaminants are migrating from this site, e.g., there is no indication as to the date or location of samples. Moreover, most all of the compounds listed are in greater concentration upgradient than downgradient. While the text justifies proceeding with an interim response action on the basis that arsenic is migrating to groundwater from this site, only two arsenic analyses are reported in this key table, both on downgradient samples. A more thorough presentation of data and date interpretation is required to justify more than monitoring for this IRA. The "preliminary" 1989 data should be included.

Response: The purpose of this document is to develop and evaluate IRA alternatives. Data used to characterize the site can be found in previous documents (Army Spill Sites Data Presentation Report [Ebasco 1988], South Plants Study Area Reports [Ebasco 1989b] and in the RMA data base). Therefore, this document did not repeat the information contained in these documents, in other than summary form. A detailed analysis of the 1989 data can be found in the Field and Laboratory Investigation Report (WCC 1989).

Comment 39: Table 2-2.

This table lists incorrectly the chemical names for DDE and DDT.

Response: The table has been corrected.

Comment 40: Table 2-3.

The title of this table should indicate that the information provided is for soil contaminants in the M-1 basins. Also, the physical properties for all of the compounds listed in Table 2-1 should be listed here as well.

Response: The text has been changed to eliminate reference to this table. The reference is now the South Plants Study Area Report (Ebasco 1989a).

Comment 41: Table 2-3, Chemical and Physical Properties of Organic Analytes in the M-1 Settling Basin Area.

Please add methylene chloride, chloroform, CPMSO₂, and DIMP to this table.

Response: See response to Shell's specific comment No. 40. The physical properties of these analytes are listed in the South Plants Study Area report.

Comment 42: Figure 2-1, M-1 Basins Field Program.

Please explain the significance of M1T1 through M1T6. M1T1 is labeled as a trench in the figure but is not mentioned in the text.

Response: The figure has been revised for clarification. M1T1 through M1T6 were exploratory trenches. Additionally, soil/sludge samples for the ISV treatability test were samples taken from M1T3 and M1T6.

Comment 43: Page 3-1, Section 3.0 Identification and Evaluation of Interim Action Technologies.

This assessment is biased toward a final remedy solution because it fails to recognize guidelines and objectives set forth by the Organizations in the FAA and TPP concerning conduct of IRA's on the RMA. Specifically,

- TPP, Section 3.3.2.7

Remediation of Other Contamination Sources.

Objective: Mitigate the threat of releases from selected "hot spot" contamination sources.

- TPP, Section 3.1

IRA's are "removal" actions.

- FFA, Section 22.5

All IRA's shall...to the maximum extent practicable be consistent with and contribute to the efficient performance of Final Response Actions.

- FAA, Section 22.6

The goal of the (IRA Alternative) assessment shall be to...select the most cost-effective alternative for attaining the objective of the IRA.

- FFA 2.3(a)

Provide for IRA's which are appropriate for the Site prior to implementation of final remedial action(s) for the Site.

IRA's are intended to be implemented on a timely basis, otherwise the benefit of taking an action prior to implementing the Final Remedy is diminished or lost. Proven, off-the shelf technologies facilitate this intent. The goal is to quickly implement the most cost effective response that will mitigate a threat of release of contaminants. The objective is clearly not remediation, although a remediation alternative is not excluded if it best meets IRA and CERCLA guidelines.

There is almost no prominence given in this assessment to these IRA objectives and guidelines. Rather, the assessment has been incorrectly conducted using CERCLA guidelines for a final remedy.

Response: See response to Shell's General Comment No. 4.

Comment 44: Page 3-1, first paragraph.

The second sentence of this paragraph causes this Section and Sections 4.0., 5.0 and 6.0 to be misdirected.

"The interim response action objectives are site-specific goals for treating soil to protect human health and the environment."

The objective of this IRA is to mitigate the threat of releases from the M-1 Basins (TPP, Section 3.3.2.7). The assessment in Section 1-2, developed the goal of creating a long-term benefit in cost or timing for RMA final remediation of this site. Accordingly, alternates should be developed and evaluated with this site-specific goal uppermost in mind. Treating the soil may be a strategy to achieve this goal, but it is not the objective of the IRA. Protection of human health and environment is one of the criteria against which the expected performance of an alternative is evaluated.

Response: The wording of the objective has been changed to more closely adhere to the Technical Program Plan.

Comment 45: Page 3-1, third paragraph.

The first bullet is the objective. The other bullets are evaluation criteria. The goal of reducing the cost of the Final Remedy should play a prominent role in the identification and evaluation of alternatives.

Response: The wording of this section has been changed to more closely adhere to the Technical Program Plan.

Comment 46: Page 3-2, second paragraph.

"Water treatment would only be conducted as part of a dewatering operation required for a soil/sludge treatment. The objective (sic) of this interim response action is source containment, removal, or treatment."

The only objective of this IRA is stated at 3.3.2.7 of the TPP. The objective is not to select a certain type of technology. This assessment consistently confuses objectives and strategies (what is expected to be accomplished versus how it will be accomplished).

The logic of the statement that water treatment would only be conducted as part of a dewatering operation is not at all clear. Groundwater interception/treatment is a widely used strategy for mitigating releases from source sites and is widely practiced on the RMA, including as interim response actions.

"Groundwater remediation is assumed to be beyond the scope of this IRA."

Agreed. However, this does not exclude using groundwater interception/treatment as a strategy to contain releases from a hot spot.

Response: See response to Shell's General Comment No. 5.

Comment 47: Page 3-3, first paragraph.

"Tables 3-1a and -1b list general response actions and associated technologies typically applied to contaminated soil and associated groundwater."

Rather than starting with a list of general response actions, this assessment could be better focused by considering possible strategies for meeting the specific IRA objectives for this specific site and then developing alternatives based on technologies appropriate for these strategies.

Response: The Army considered it appropriate to look at a wide range of strategies, and to carry through alternatives associated with each of these strategies. Consequently, the approach was to describe to the reader applicable technologies, and then use these to develop the desired wide range of alternatives.

Comment 48: Page 3-4, last paragraph.

To the list of containment technologies should be added groundwater interception, treatment and reinjection. This is a practical containment strategy as is demonstrated by control systems presently in operation on the RMA.

Response: See the response to Shell's General Comment No. 5.

Comment 49: Page 3-5, last paragraph.

Surface capping does not necessarily need to be used in conjunction with other groundwater measures to be effective in reducing contaminant leachate production from near-surface soils.

Response: Agreed. The text has been changed to clarify this point.

Comment 50: Page 3-6, fourth paragraph, last sentence.

A surface capping system can be very effective in some circumstances even if not constructed in conjunction with a slurry wall.

Response: Agreed. A surface cap is carried through as Alternative 5.

Comment 51: Page 3-6, 3.2.3.3.

How would potentially contaminated soils generated during slurry wall construction be handled? This could dramatically increase the cost of slurry wall construction, thus making grout curtains or sheet piles more cost-effective. If an inexpensive method of dealing with excavated soils is not readily apparent, either sheet piling and/or grout curtains should be retained for further consideration.

Response: Potentially contaminated soils excavated during slurry wall construction will be placed within the slurry wall and used in regrading the site to control runoff and runoff before cap construction.

Comment 52: Page 3-8, first paragraph.

Sheet piling may or may not be more expensive than a slurry wall; it depends upon the site and the situation.

Response: Agreed. However, sheet piling may be less effective at this site than a slurry wall because of the sandy soils, which could prevent sealing between the plates and could therefore result in an ineffective contaminant system.

Comment 53: Page 3-9, 3.2.5 Treatment.

The text should explain why treatment is considered as part of an interim response strategy. Will dedicated treatment processes be implemented for all individual IRA sites? This would not be cost-effective and may not be consistent with final remedial actions. Most of the treatment technologies discussed in this Section seem unsuited for an interim response action

because substantial development and site-specific testing would be required with the prospect that such testing will determine that a technology is not feasible or is not cost-effective.

Response: Treatment technologies considered as IRA alternatives for the M-1 Settling Basins (in-situ vitrification and chemical fixation) have already been bench-tested using M-1 Basin sludge. Nothing in the Federal Facility Agreement or the Technical Program Plan precludes the consideration of treatment technologies. Only treatment technologies which would meet the IRA objective to mitigate the threat of release from the source are developed into alternatives. Treatment alternatives undergo the same evaluation as other alternatives with regard to implementability, timeliness, cost-effectiveness, and consistency with the final remedy to the maximum extent practicable.

Comment 54: Page 3-9, Section 3.2.5.1.1 - In-situ Vitrification.

The sediment/sludge in the settling basins is rich in lime. The lime is refractory and may require much higher temperatures unless it is mixed with other components to reduce slagging temperatures.

Response: Bench testing has shown that a melt can be maintained at temperatures between 1600° and 1700° C.

Comment 55: Page 3-10, first paragraph.

Arsenic and mercury would be volatilized by in-situ vitrification and would need to be collected along with any volatile organics or byproducts.

Response: Agreed. The text has been changed.

Comment 56: Page 3-10, fourth paragraph.

Chemical fixation is known to work better on metals than organics.

Response: Agreed. Metals are the primary contaminants at the M-1 Settling Basins.

Comment 57: Page 3-12, Section 3.2.5.2.1.1.

The matrix is lime-rich, so pH is already high.

Response: Agreed. However, this section was meant to be a general introduction to the process.

Comment 58: Page 3-13, Section 3.2.5.2.2.

How are metals leached from high lime sludges without extreme reagent additions?

Response: Agreed. The text states this on page 3-14, paragraph 3.

Comment 59: Page 3-14, last paragraph.

A major disadvantage of this technology is that a large volume of solvent (usually water) containing soil contaminants and other soluble soil constituents is produced which must then be treated.

Response: Agreed. This technology is not considered further.

Comment 60: Page 3-15, 3.2.5.4 Off-site Treatment.

Why is the list of possible applicable technologies different based on whether the technology is applied onsite or offsite. Probably because of the availability of offsite facilities, however, this is not discussed.

Response: This list is limited by the availability of offsite facilities.

Comment 61: Page 3-16, first paragraph.

Solidification may work for metals but has not been proven for organics.

Response: At least one program in EPA's Superfund Innovative Technology Evaluation (EPA/540/M5/89/001, March 1989) has shown promising results in the fixation of PCBs and semi-volatile organics (EPA 1989).

Comment 62: Page 3-18, 3.2.7.

See comment 53.

Are seasonal changes so reliable and drastic as to be able to predict that no dewatering would be necessary if the IRA were implemented in the dry season?

Response: Please see the discussion in response to Shell's Specific Comment No. 53.

The alternatives carried through to the final evaluation would not be greatly affected by the presence of groundwater in the soil/sludge. The discussion of dewatering and water treatment is included primarily as a contingency.

Comment 63: Page 3-18, Section 3.2.7.1.

If the sludges are just saturated and relatively impermeable, the use of wells or trenches is not practical.

Response: Agreed. Dewatering processes are considered only for either dewatering the excavation or lowering the water table. None of the alternatives developed require dewatering of the saturated sludges.

Comment 64: Page 3-19, Section 3.2.7.1.3.

Why suggest a drum filter? This is not a good application for this type of filter.

Response: A drum filter was described as one of several typical filtration methods and was not intended to be necessarily the selected unit operation. If any type of filtration is determined to be necessary during design, the type of filter to be used will be chosen at that time.

Comment 65: Page 3-20, second paragraph.

Storage of groundwater for treatment in the Final Remedy should be considered in lieu of constructing a dedicated facility for treatment of a relatively small, discrete volume of groundwater. Storage volume probably already exists in the South Plants area.

Response: This option could be considered during the design phase.

Comment 66: Page 3-21, third paragraph.

Granular Activated Carbon (GAC) is currently used on the RMA site for water and groundwater treatment and should certainly be considered for this application. Where some contaminants are not efficiently removed by GAC, it is very common practice to couple carbon adsorption treatment with another technology, e.g., air stripping.

Response: The groundwater at the M-1 Settling Basins has contaminant concentrations several orders of magnitude higher than groundwater being treated by GAC elsewhere at RMA. Excessive carbon usage rates for these high concentrations makes GAC inappropriate for this site.

Comment 67: Page 3-23, second paragraph.

If a technology requires process development, it is not suited for an interim response action, particularly if proven technologies, e.g., GAC, are available.

Response: Agreed. This technology has been removed from further consideration.

Comment 68: Page 3-23, second paragraph.

Rotary Biological Contractors are inefficient on chlorinated hydrocarbons as well.

Response: Agreed. This technology has been removed from further consideration.

Comment 69: Page 3-28, last paragraph.

The reason given for not considering reinjection of groundwater, i.e., clogging of well screens, is inconsistent with the fact that reinjection systems have been used in the RMA for many years and in most instances clogging has not been a serious problem.

Response: Use of well reinjection at RMA has been plagued with clogging of well screens in the past. Nevertheless, reinjection can be accomplished using percolation beds or trenches without risking these potential clogging problems. The type of reinjection, if necessary, would be determined during design.

Comment 70: Page 3-29, 3.2.7.3.3 and 4.

These Sections should be reviewed for consistency with the Hydrazine Blending and Storage IRA Decision Document.

Response: This document has been reviewed. A UV/oxidation system has been proposed; however, the implementation schedule for these IRAs may not necessarily coincide.

Comment 71: Page 4-1, last paragraph.

The containment strategy of intercepting groundwater, treating and reinjection should be an alternative considered. Also, removal and placement in a temporary waste pile, e.g., as with Basin F solids, would appear to be a logical strategy and should be considered.

Response: See responses to Shell's General Comments Nos. 5 and 7.

Comment 72: Table 4-1a, Table 6-1.

What justifies the conclusion that the No Action, Monitoring, and Institutional Controls alternatives are not protective of Human Health and the Environment?

Response: The objective of this IRA is to mitigate the threat of releases from the M-1 Settling Basins. The M-1 Settling Basins have been evaluated as being a source of groundwater contamination. Because a threat of release to groundwater does exist, No Action, Monitoring and Institutional Controls do little or nothing to respond to this threat.

Comment 73: Page 4-1, 4.0 Development and Evaluation of Alternatives.

The introduction to this Section ignores the objective of this IRA, the intent of IRA's and IRA guidelines as set forth in the FFA and the TPP. It also ignores the goal developed in Section 1.2 of reducing the cost, or accelerating implementation, of the Final Remedy. These should provide the necessary "anchor" for judgements applied in both the development and evaluation of alternatives. Without relating to them, this assessment becomes aimless.

Response: All of the alternatives developed are capable of meeting the objective of this IRA. Cost, implementability, and consistency with the final remedy are all considered during alternative evaluation.

Comment 74: Page 4-3, first paragraph.

In the absence of a site assessment which defines the contaminants emanating from the basins and the aerial extent of groundwater impact, it is premature to specify details of a monitoring program, such as suite of analytes, frequency of sampling and sampling wells.

Response: Only conceptual alternative designs are presented in the IRA Alternative Assessment. The monitoring program outlined is appropriate for the location and types of contaminants in this area. As with any of the alternatives, changes to the conceptual design may be made during final design.

Comment 75: Page 4-3, third paragraph.

Why is air monitoring required for non-invasive strategies? Isn't the CMP sufficient?

Response: Air monitoring has been deleted for the non-invasive strategies.

Comment 76: Page 4-4, 4.1.4.2 Construction of a Multi-layered Cap.

Why is such a complex cap required for temporary capping (see last sentence of 4.1.4)?

Response: This alternative would be designed to meet ARARs, to the maximum extent practicable. This cap description is one that might typically be required for capping of hazardous waste piles. However, the final details of the cap design would be established during the design phase.

Comment 77: Page 4-5, Section 4.1.5.

Downward percolation of rainfall on well vegetated soils on the RMA is very low. The incremental benefits (i.e., reduced deep percolation) associated with constructing a "Multi-layered Cap" as described in this section seem very limited and probably not worth the additional costs. Perhaps all that is warranted in this alternative is to see that a good soil cover, adequate grade for surface water drainage, and good vegetative cover are established. The cost may be much lower than constructing the "Multi-layered Cap" described, and the difference in deep percolation through the two caps would likely be insignificant.

Response: See response to Shell's Specific Comment No. 76.

Comment 78: Page 4-5, 4.1.6 Alternative 6.

Why is a slurry wall a part of this alternative?

Consideration would have to be given to the possibility that adverse chemical reactions could occur as a result of the high energy input involved.

Response: The slurry wall is used to provide a temporary barrier to groundwater recharge in the vitrification area, as is stated in Section 4.1.6.1. The need for and depth of the slurry wall would be determined during design. The temperature gradients generated in the ISV process are very large. Ambient temperatures usually exist within one foot of the progressing m.l.t.

Comment 79: Page 4-6, third paragraph.

Instead of 700,000 gallons of steam, 700,000 gallons of water in the form of steam is probably meant.

Response: The text has been changed.

Comment 80: Page 4-6, third paragraph.

The described gas handling system does not appear adequate to handle the poisonous arsenic, cadmium, and mercury fumes or vapors. A wet electrostatic precipitator should be included in the design of the system to effectively reduce the concentration of these metals in the gas stream which is discharged to the atmosphere. The off-gas stream may also contain a very flammable mixture of organics due to the volatilization of benzene, chlorobenzene, MIBK, xylenes, etc.

Response: This document is intended to provide a conceptual design of each alternative. The offgas system will be closely scrutinized during final design to be certain it will handle all possible contaminants in the offgas stream. The ISV process does not merely volatilize the above-mentioned organics. These compounds would either be pyrolyzed in the melt or rapidly oxidized as they migrated to the surface. A flammable mixture of organics is not anticipated.

Comment 81: Page 4-6, fourth paragraph.

The condensate will also contain cadmium and a mixture of organics. However, cadmium is more amenable to precipitation by pH adjustment than are arsenic and mercury. Due to the presence of a yet undetermined mixture of organics, the treatment of the wastewater will likely be difficult and not amenable to discharge to a percolation bed.

The discussion in this paragraph (as well as the previous paragraph) does not address the generation and disposal of solid wastes from the treatment processes. For example, the disposal of the metals removed from the wastewater is not addressed.

Response: These details are best addressed during final design. The vast majority of cadmium will remain in the melt. Any metals that do volatilize will be condensed and collected in the quench water and scrubber water. This water would most probably be treated with a combination of demonstrated industrial wastewater treatment (such as pH adjustment and precipitation) and filtration through diatomaceous earth and activated carbon. The overwhelming majority of organics will either be pyrolyzed or oxidized during the ISV process and therefore will not hinder subsequent wastewater treatment.

Comment 82: Page 4-7, Section 4.1.7.

The chemical fixation of the wastes does not decrease the mobility of organics, but does increase the volume of the wastes.

Response: Some chemical fixation processes have been shown to be successful at immobilizing certain organic compounds. Whether a fixation process can be developed to fix the organics present at this site would need to be determined during a treatability test.

Comment 83: Page 4-7, 4.1.7 Alternative 7.

It is not cost-effective to construct an onsite landfill for each RMA site. An effort should be made to relate this interim response action to the Final Remedy, e.g., the prospect that the Final Remedy may include a landfill and soil treatment process(es) and that, for cost-effectiveness, redundancy should be avoided where possible.

Response: The term "landfill" has been replaced with "temporary waste pile" to clarify the intent of this storage unit.

Comment 84: Page 4-8, third paragraph.

More important is which organic contaminants are not immobilized by chemical fixation. This technology is highly problematic if some of the organics leach from the matrix. Extensive testing would be required to determine a recipe for fixation with the possibility that none will work or be cost effective.

Response: Agreed. This is a consideration of the long-term effectiveness criterion. The potential for subsequent leaching of organics after treatment is one reason chemical fixation is eliminated from consideration in Section 6.2.

Comment 85: Page 4-9, second paragraph.

See Comment No. 83.

Could a landfill be constructed "in the vicinity of the M-1 Settling Basins" without possibly interfering with final remedial actions?

Response: The location of the temporary waste pile would be chosen during design and would, to the maximum extent possible, be located to provide minimal interference with the final remedy.

Comment 86: Page 4-12, 4.2 Alternative Evaluation Criteria.

The preeminent criteria is the effectiveness of an alternative in achieving the objective of this interim response action, i.e., to mitigate the threat of release of contaminants from the M-1 Settling Basins with the goal of providing a benefit to cost or timing of RMA remediation (Section 1.2). This criteria is not addressed in this Section or anywhere else in this assessment.

This Section only defines CERCLA evaluation criteria. An alternative Assessment should relate these criteria to specific site conditions and the specific alternative being evaluated. There should be more focus in this Section 4.0 on this site and on the interim response objective and guidelines. The questions listed under the evaluation criteria sections may be generally applicable to Superfund sites but many of them do not seem applicable to an interim response action at this specific site.

Response: The alternative evaluation has been expanded in Section 6.2 of the final alternatives assessment to discuss these points in greater detail.

Comment 87: Page 4-13, second paragraph.

"How each alternative addresses each of the evaluation criteria will be presented in greater detail in the IRA Decision Document. However, a summary of alternative evaluation criteria is presented in Tables 4-1a and 4-1b."

Discussion of how the alternatives address evaluation criteria (and most importantly the objective of the IRA) is the whole point of an Alternatives Assessment document and should be included. The summaries in Tables 4-1a and 4-1b are too brief to be of value. How can the Other Organizations and the State make meaningful comment on the ranking of alternatives in Section 6.0 if there is no such discussion?

Response: All alternatives developed would meet the IRA objective. The alternatives evaluation has been discussed in greater detail in Section 6.2 of the final alternatives assessment.

Comment 88: Page 4-13, 4.2.1 Effectiveness.

"Some of the questions addressed in this evaluation are as follows:"

None of these questions appear to be addressed in this assessment except in very general terms in Tables 4.1a and -1b. For example, what risks are mitigated by the alternatives described? Section 1.2 states that this site does not appear to pose a significant risk to human or biota receptors at this time. The site assessment in this evaluation does not demonstrate the M-1 Settling Basins are a source of groundwater contamination.

Achievement of the objective of this interim response action should be the preeminent criterion considered in this Section.

Response: The objective of this IRA is to mitigate the threat of release from the source. All alternatives carried forward to the expanded evaluation in Section 6.2 meet this objective. Section 2.2.2 discusses the evaluation of the M-1 Settling Basins as a source of groundwater contamination.

Comment 89: Page 4-15, 4.2.2 Reduction in Mobility, Toxicity and Volume.

None of the issues listed are discussed with specificity to the respective alternative interim response action at this site.

Response: See response to Shell's Specific Comment No. 87.

Comment 90: Page 4-16, 4.2.3 Implementability.

None of the issues listed are discussed with specificity to the respective alternative response action at this site.

Response: See response to Shell's Specific Comment No. 87.

Comment 91: Page 4-17, 4.2.4 Overall Protection of Human Health and the Environment.

The presence of a threat from this site to human health or the environment is not discussed. What is the basis for evaluation of alternatives against this criterion at this site?

Response: The Federal Facility Agreement lists the M-1 Settling Basins as a "hot spot" for which IRA Alternative Assessment is required. The objective of this IRA is to mitigate the threat of releases from the M-1 Settling Basins. The M-1 Settling Basins are evaluated as being a source of arsenic contamination to the groundwater. The implementation schedule for both the

Decision Document and the Response Action itself makes it difficult to collect a sufficient amount of data for the comprehensive risk assessment required to determine whether a significant risk to human health or the environment exists.

Alternatives were evaluated based on their ability to mitigate the threat of releases at the site.

Comment 92: Table 4-1a.

The title of this table states that these are threshold criteria for the Motor Pool Area. Is the table for another IRA site or is it mislabeled?

Under Overall Protectiveness, what specifically is "the risk" against which this criterion is applied?

Under Compliance with ARAR's, at this point in the IRA process ARAR's are identified only preliminarily. Statements under this column should be qualified accordingly. Also, the ability of the respective alternative to meet an ARAR may not be known prior to testing or design.

Response: The table title has been corrected.

The risk referred to here is any health risk to the community and the environment resulting from the presence of arsenic contamination at the site.

For any alternative implemented as an IRA at the M-1 Settling Basins, ARARs would be met to the maximum extent practicable.

Comment 93: Page 5-1, second paragraph.

"Since the Federal Facility Agreement states that the IRA decision document should select the most cost effective alternative which meets the threshold criteria,..."

More accurately, the FFA (Section 22.6) states: "The goal of the assessment shall be to ...select the most cost-effective alternative for attaining the objective of the IRA" (emphasis added). The objective of the IRA should not be confused with CERCLA evaluation criteria

Response: The text has been changed.

Comment 94: Page 5-1, third paragraph.

"A present worth analysis is also presented to compare alternatives with different project durations."

Since project life is the same (5 yrs) for all alternatives, the present worth analysis is used here to facilitate comparison of alternatives with different expenditure patterns during the five year period.

Response: The text has been changed to replace "project durations" to "expenditure pattern."

Comment 95: Tables 5-1 to 7.

Why are air monitoring costs in year 0-1 for alternatives involving excavation and/or treatment the same as for alternatives 2-5 which do not? Experience of the Basin F IRA implementation should indicate that air monitoring will be substantially greater for alternatives involving excavation and/or treatment.

Response: Only conceptual alternative designs are presented in the IRA Alternatives Assessment. The monitoring program outlined is appropriate for this purpose. As with any alternative, changes to the conceptual design may be made during final design.

Comment 96: Table 5-1, (follows page 5-10).

In general, the costs presented in this table appear to be excessive. For example, the O & M for labor for air sampling is \$80,000, but the air sampling of this site should not require this level of effort. The costs of sampling existing monitoring wells also appears to be inflated. These inflated monitoring costs are carried forward to the estimated costs for the various treatment alternatives.

Response: See response to Shell's Specific Comment No. 95.

Comment 97: Table 5-6.

Why is cap maintenance included in the cost of this alternative? No mention of a cap is made in 4.1.7.

Response: The cap is for the temporary waste pile.

Comment 98: Page 6-1, 6.0 Conclusions.

The preeminent criterion as developed in Section 1.2, i.e., to affect the cost or timing of the Final Remedy, is not addressed in this classification. (Neither is it addressed under the CERCLA criterion of Effectiveness in Section 4.0). This classification is essentially a ranking by ability to meet CERCLA criteria.

Response: See response to Shell's Specific Comment No. 87.



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION VIII

999 18th STREET - SUITE 500
DENVER, COLORADO 80202-2405

OCT 11 1989

Ref: 8HWM-SR

Mr. Donald L. Campbell
Office of the Program Manager
Rocky Mountain Arsenal
ATTN: AMXRM-PM
Commerce City, Colorado 80022-2180

Re: Rocky Mountain Arsenal (RMA)
Alternative Assessment of Interim
Response Actions (IRA) for Other
Contamination Sources: M-1
Settling Basins, September 1989.

Dear Mr. Campbell:

We have reviewed the above referenced document and have the enclosed comments. We wish to emphasize our concern that the document does not evaluate the potential for continued migration and treatment of the arsenic plume from the M-1 Settling Basins. This possibility should be addressed, given the inability of the boundary or other IRA intercept and treatment systems to treat arsenic.

The document does not adequately assess the M-1 Settling Basins as a source of groundwater contamination nor does it consider interception and treatment of the groundwater near the source as a remedial alternative for this IRA. We do not agree with the limitation of no groundwater remediation as part of this IRA, and note that several IRAs are devoted partially or completely to the interception and treatment of groundwater.

Our concerns on associated ARARs issues are addressed in a separate letter. Please contact Linda Grimes at (303) 293-1262, if you have questions on this matter.

Sincerely,

Connally Mears
EPA Coordinator for RMA Cleanup

cc: Jeff Edson, CDH
David Shelton, CDH
Vicky Peters, CAGO
Lt. Col. Scott Isaacson
Chris Hahn, Shell
R. D. Lundahl, Shell
John Moscato, DOJ
Robert Foster, DOJ

**RESPONSES TO THE EPA'S COMMENTS ON THE ALTERNATIVES ASSESSMENT
OF THE INTERIM RESPONSE ACTIONS FOR OTHER CONTAMINATION SOURCES:
M-1 SETTLING BASINS
NOVEMBER 1989**

GENERAL COMMENTS

Comment 1: Page 2-1, Section 2.1.1.2, please expand the text to state the source and nature of the solids, referenced here, which filled the basins.

Response: The solids referenced here consist of a lime sludge generated during the "neutralization" of waste streams produced in the lewisite complex, the acetylene plant, the thionylchloride plant and the arsenic trichloride plant in the South Plants area (Ebasco 1987). The waste material sent to the basins consists predominantly of arsenic salts such as arsenic oxide and arsenic trichloride, mercuric catalyst discarded from the lewisite plant, and lime sludge from the acetylene plant and from the neutralization process.

Comment 2: Page 2-1, Section 2.1.1.2, please state the process used to precipitate the arsenic and the chemical form of the arsenic in the solids.

Response: The waste streams from the lewisite complex were sent to the four disposal reactors at the lewisite disposal facility. There, they were neutralized with calcium hydroxide. After neutralization, they were sent to the M-1 Basins to settle. The current chemical form of the arsenic is unknown since analytical methods used during site characterization indicate only "total" arsenic in soil and "total" and "dissolved" arsenic in groundwater. The chemical state of the arsenic could affect the effectiveness of chemical fixation. Treatability testing of that technology would be required.

Comment 3: Page 2-5, Section 2.2.2, the first paragraph in this action concludes that the arsenic in the groundwater is associated with suspended solids. The second paragraph concludes that the arsenic is dissolved in the groundwater. Please explain this apparent discrepancy.

Response: Samples taken in the spring of 1989 were analyzed for filtered and unfiltered arsenic using standard USATHAMA methods. The historical data presented in the report did not specify which analytical methods were used. Therefore, this discrepancy cannot be positively explained. One possible explanation may be variable sample preparation or preservation methods.

Comment 4: Page 2-13, Section 2.3.3, the statement that the synergism between metals reduces the toxicity is inappropriate in this text and cannot be substantiated for this site. The metals would be taken up by the plants and could be toxic to herbivores.

Response: This section has been significantly modified to address the concerns of the reviewing organizations.

Comment 5: Page 2-13, Section 2.3.4, the text indicates that metal organic chelates are a nonsoluble metals form. It is expected that metal organic chelates would be soluble. The text should be amended.

Response: The text has been changed.

Comment 6: Page 2-15, Section 2.5, the text states that dewatering would not be required for this IRA, since the alluvial groundwater is 8 feet below the surface. It is possible that groundwater would be encountered during any excavation of contaminated soils in the basins even during seasonal lows in water levels. The document needs to address this possibility more directly.

Woodward-Clyde Consultants

- Response:** Possible dewatering and water treatment options are discussed in Section 3.2.7. A decision on which method(s) to use, if necessary, will be made during design.
- Comment 7:** Page 3-2, Section 3.1.2, please expand the text to present the basis for the statement that groundwater contaminants appear to be originating from the South Plants Area. Further, please specify which contaminants are being addressed.
- Response:** Based on groundwater contaminant data reported to the RMA data base and summarized in Table 2-2, there does not appear to be a significant increase in organic contaminants because of the M-1 Settling Basins. Also, the soil samples taken from within and in the vicinity of the M-1 Settling Basins do not indicate that the basins are a source of organic contaminants. Therefore, the source of these contaminants is upgradient of the M-1 Settling Basins, and it is assumed that the source is the South Plants area. See Table 2-2 for the contaminants found in this area. Section 3.1 has been revised to address comments from the Organizations and the State, and this statement has been deleted. The major contaminant apparently contributed to the groundwater by the M-1 Settling Basins is arsenic.
- Comment 8:** Page 3-2, Section 3.1.2, the text states "Groundwater remediation is assumed to be beyond the scope of this IRA." This assumption needs to be justified. Considering that the M-1 Settling Basins are an identified source of arsenic contamination in the groundwater and that none of the boundary or other IRA intercept and treatment systems are designed to treat arsenic, the document needs to quantify the extent of, and assess the potential remediation of, arsenic contamination in the groundwater. We do not agree with the elimination of groundwater remediation as an objective of this IRA.
- Response:** The objective of the IRA is to mitigate the threat of releases from the M-1 Settling Basins. The Army agrees that the contaminated alluvial groundwater emanating from the South Plants will need to be addressed in the final remedy. However, to attempt to address the groundwater contamination contributed specifically from the M-1 Settling Basins would require extensive investigation to sort out what contamination was emanating from what source.
- Comment 9:** Page 3-4, Section 3.2.1, the text states "...apparent relatively immobile compounds present at the M-1 Settling Basins...". Please provide further explanation of the meaning of this statement and an assessment of the adequacy of the number of current monitoring wells.
- Response:** This statement has been removed from the text. Wells 01083 and 36193 were installed during the 1989 field program for this task to provide adequate groundwater contamination information. These wells, sampled in conjunction with 01503, 01504, and 01524, are adequate to monitor contaminant migration from the M-1 Settling Basins.
- Comment 10:** Page 3-8, the option to lower the groundwater table by dewatering should be considered. This would enable excavating to occur despite of unfavorable groundwater levels.
- Response:** Dewatering would be conducted if necessary. Methods of dewatering are discussed in Section 3.2.7.1. The presence of groundwater in excavated soil would have little effect on the alternatives developed for the M-1 Settling Basins and presented in Section 4.0.
- Comment 11:** Page 3-13, Section 3.2.5.2.2, first paragraph, the fourth sentence states that "...the solution is recycled until the contaminant concentration in both the soil and treatment solution are equal." The text should be corrected to say "...are in equilibrium."
- Response:** The text has been changed.
- Comment 12:** Page 3-16, Section 3.2.6.1.1, Hazardous Waste Landfill, there is discussion about a hazardous waste landfill for onsite "disposal" as part of this IRA. It should be noted that the final decision on this IRA has to be consistent with the final remediation of the overall RMA site. Since it

is premature to assume that onsite "disposal" will be consistent with the final remediation, and since 22.1 (1) of the FFA specifies "temporary storage", please restate "onsite temporary storage," and that future remediation may include other actions such as excavation, treatment, and placement.

Response: The text has been changed.

Comment 13: Page 3-21, Section 3.2.7.2.1. Carbon Adsorption, last paragraph of this section makes the statement that volatile halogenated organics "...are among the least sorbable species with reference to GAC" and that GAC would not be considered further. It should be noted that there are several GAC treatment operations on the RMA site which are specifically designed to remove volatile halogenated organics. The text should be amended to clarify what is meant by this statement, and GAC should be retained as a potential water treatment technology.

Response: The groundwater at the M-1 Settling Basins has contaminant concentrations several orders of magnitude higher than groundwater being treated by GAC elsewhere at RMA. Excessive carbon usage rates for these high concentrations makes GAC inappropriate for this site. The text has been changed to clarify this point.

Comment 14: Page 3-28, Section 3.2.7.3.1, Reinjection, in this paragraph, injection of water is not considered further because of microbial growth plugging well screens. It should be noted that reinjection is presently done on the RMA site and appears to be technically feasible; so, it is not appropriate to screen out reinjection in this section.

Response: The use of wells for reinjection was rejected because of potential fouling problems. Reinjection through percolation beds or trenches is considered. The text has been changed to clarify this point.

Comment 15: Page 3-28, Section 3.2.7.2.7, Ion Exchange, the last sentence states that both "...anion and cation exchange resins were used in the study, since arsenic may exist in several oxidation states." It should be noted that arsenic exists in water as an anionic complex regardless of oxidation state; but most researchers have found that regardless of the removal process for arsenic that it is most effective to pre-oxidize the arsenic to the +5 oxidation state.

Response: Agreed. The sentence has been deleted.

Comment 16: Page 3-29, please state whether the feasibility of the treatment of groundwater in the proposed CERCLA Wastewater Treatment Plant was evaluated.

Response: The treatment of groundwater in the proposed CERCLA Wastewater Treatment Plant was not evaluated in this IRA Alternatives Assessment because the treatment plant is still in development, and the project has an unknown implementation schedule. Should dewatering and water treatment be necessary, options such as those described in Section 3.2.7 or any new options such as the CERCLA Wastewater Treatment Plant would be considered during the design and implementation of this IRA.

Comment 17: Table 4-1a, for three alternatives (no action, monitoring, and institutional controls), the table indicates compliance with ARARs. The table should indicate that there are no ARARs for these alternatives. In order to determine the acceptability of these alternatives, a risk analysis would have to be done.

Response: The table has been revised. Monitoring and institutional controls can be designed and implemented so that location-specific or action-specific ARARs (to the extent they exist) are met. Since no treatment is involved, ambient or chemical-specific ARARs will not be met. The no action alternative would not trigger location or action-specific ARARs, nor would it meet ambient or chemical-specific ARARs.

Comment 18: Page 4-3, Section 4.1.2, Monitoring, it is stated that monitoring will be done by quarterly sampling and analyses, and that this information will be included as part of the Comprehensive Monitoring Program (CMP) as RMA. Please state that the CMP is committed to doing this operational monitoring on a quarterly basis.

Response: The monitoring on a quarterly basis will be performed during implementation of this IRA, as part of this IRA. The statement that this information will be included as part of the CMP implies that the yearly CMP analysis of groundwater will include this information.

Comment 19: Page 3-29, last paragraph, please detail the "discharge limitations" for storm sewer discharge which make it appear a more feasible option than discharge to the RMA Sewage Treatment Plant (STP). Such limitations for a new discharge would have to be developed and would likely roughly equal those for the STP.

Response: Discharge limitations will be developed during the preliminary design phase of the project. Whether the additional capacity and effluent quality of the selected water treatment unit could be introduced into the RMA sanitary sewer is as yet undetermined. Therefore, until these limitations are set, discharge to the RMA STP cannot be discounted. The text has been changed to reflect this fact.

Comment 20: Page 4-5, first paragraph, please explain the consistency of the 360° slurry wall with the final remedy.

Response: The purpose of the 360° slurry wall constructed for this alternative is to hydraulically isolate the M-1 Settling Basins so that groundwater inflow does not interfere with the ISV process. Materials excavated during slurry wall construction would be placed within the slurry wall and vitrified with the other M-1 Settling Basins soil/sludge. This would be consistent with the final remedy because ISV destroys the organics and permanently immobilizes the metals.

STATE OF COLORADO

COLORADO DEPARTMENT OF HEALTH

4210 East 11th Avenue
Denver, Colorado 80220
Phone (303) 320-8333

October 11, 1989



Roy Romer
Governor

Thomas M. Vernon, M.D.
Executive Director

Mr. Donald Campbell
Deputy Program Manager
Office of the Program Manager
AMXRM-PM, Bldg. 111
Commerce City, Colorado 80022-2180

Re: State comments on Draft Final Alternative Assessment of the
Interim Response Actions for Other Contaminated Sources - M1
Settling Basins.

Dear Mr. Campbell:

The State submits the following comments regarding the Draft
Final Alternative Assessment of the Interim Response Actions for
Other Contaminated Sources - M1 Settling Basins.

During the October 5, 1989 Committee meeting, the State was
informed by a contractor for the Army that numerous additional
samples had been taken and analyzed prior to issuance of this
report. According to your contractor, these data, including 30
soil samples and 7 ground water samples were omitted from the
report because the report contained sufficient historical
information in order for the reader to evaluate the
alternatives.

In order for the State to adequately provide comments on this
document, we urge the Army to include all available data in the
report. The State had to modify significant portions of their
comments regarding this interim action based on the data
presented during the October meeting.

If you have any questions, please feel free to call.'

Sincerely,

Jeff Edson, Project Manager
Hazardous Materials and Waste Management Division

cc: Michael R. Hope Esq.
John Moscato, Esq.
Chris Hahn
Edward J. McGrath, Esq.
Connally Mears
Bruce Ray, Esq.
Lt. Col. Scott Isaacson
Tony Truschel

**RESPONSES TO THE STATE OF COLORADO'S COMMENTS ON ALTERNATIVE
ASSESSMENT OF INTERIM RESPONSE ACTIONS FOR OTHER
CONTAMINATION SOURCES M-1 SETTLING BASINS
NOVEMBER 1989**

GENERAL COMMENTS

Comment 1: In the M-1 Settling Basins IRA Alternative Assessment, the Army contemplates a myriad of response actions that apparently provide for ultimate remediation of this particular source. Such activities are beyond the scope of the "other sources IRA" as discussed in 1987 when the State concurred in the designation of this IRA. The original objective envisioned by the State was to expeditiously contain or remove source material and thereby halt further migration of highly concentrated waste into ground water or soils. The alternatives presented by this report include several relatively innovative technologies which are currently in various experimental stages but remain basically unproven. Although this document seems to indicate that they could be implemented within a year, this seems unlikely given the detailed field proofing and pilot testing that would be necessary to ensure proper performance. Inclusion of these time consuming efforts in the interim action process will unduly delay implementation. In addition, adoption of such treatment alternatives on a source by source basis may prove to be inconsistent with the final remedy selected at the Arsenal, or result in costly duplicative efforts.

The most obvious and appropriate interim response alternative, excavation and temporary storage in a sufficiently protective waste pile, was not even considered. The report should therefore be revised to include this alternative. The report should also include any proven treatment technologies that could be implemented on an expedited basis and would be reasonably certain to achieve agreed upon cleanup criteria, if such technologies currently exist.

Response: The Army disagrees with the State of Colorado's opinion that treatment alternatives are specifically excluded from the scope of the "other sources IRA." Paragraph 22.6 of the Federal Facility Agreement states that "The goal of the assessment shall be to evaluate appropriate alternatives and to select the most cost-effective alternative for attaining the objective of the IRA." The objective of the IRA is "To mitigate the threat of releases from the M-1 Settling Basins." The Army has evaluated a broad range of alternatives including, but not limited to, containment, treatment and temporary storage. The Army has evaluated these alternatives based on criteria recommended in the CERCLA Guidance with emphasis on implementability and consistency with a final response action. Therefore, technically immature treatment alternatives or alternatives with excessive implementation periods would be discounted in the evaluation process. If a treatment alternative is selected, it would necessarily be one which could be implemented with minimal field testing and be completed in a time frame consistent with the overall IRA implementation schedule.

Excavation and temporary storage was considered and discounted early in the selection process. The sludge currently exists sub-grade with no significant impacts to the community or biota. The only significant impact is on alluvial groundwater quality. The excavation operation could potentially release possible lewisite or Army agent degradation products present in the sludge. Any precipitation runoff or leachate collected from the temporary storage pile would require subsequent treatment. The Army sees no benefit in the excavation of this material only to store it, untreated, onsite. There are less expensive containment alternatives (slurry wall and cap), and treatment options that are better suited to this particular site.

Comment 2: Data presented at the October 5, 1989 RMA Committee Meeting indicated that the Army has concluded that the M-1 basins are a major source of groundwater contamination, particularly arsenic. The horrendous concentrations detected in the vicinity of these ponds are particularly disturbing given the fact that they will not be treated either at the Basin A Neck treatment

facility or at the boundary systems, none of which, despite repeated State protestations, treat inorganics. The State again strongly urges the Army to address inorganic contamination at the Arsenal on an expedited basis.

Response: The Army fully intends to address inorganic contamination at the arsenal during consideration of final remediation at RMA. The objective of this IRA is to mitigate the threat of releases from the M-1 Settling Basins. The Army's interpretation of this objective is that the contamination source will be addressed in an expeditious manner. To include groundwater treatment in this IRA runs the risk of slowing the implementation schedule.

Comment 3: The descriptions of the evaluated technologies do not indicate the degree of cleanup that would be achieved by their implementation. The ARARs analysis offers neither ARARs nor proposed remedial objectives for these technologies. Without knowing the degree to which each alternative will succeed in removing or immobilizing contaminants, the parties cannot apply the ARARs and protectiveness evaluation criteria to determine the most appropriate response action.

Response: Action-specific ARARs, and location- and chemical-specific ARARs should be met to the maximum extent practicable.

Comment 4: At the October 5, 1989 RMA Committee Meeting, Army contractors presented additional field data regarding the M-1 Basins, among other sources. Although this sampling had been performed some months previously, the data were not incorporated into the Alternatives Assessment document. The absence of these data hampered the State's ability to thoroughly review and analyze the Assessment. All data obtained on these basins, and conclusions drawn from these data should be included in this report and subject to review by the parties.

Response: In order to meet the schedule, it was necessary to issue the Alternative Assessment of Interim Response Actions for other contamination sources, M-1 Settling Basins, to the Organizations and the State for comment prior to the validation and distribution of the laboratory data from samples collected during the field investigation for this Task Order. Data from the 1989 field investigation are presented in detail in the Field and Laboratory Investigation Report for this investigation (WCC 1989). This alternatives assessment summarizes the data, with data from previous investigations, in Tables 2-1 and 2-2. These data confirm that the M-1 Settling Basins are a source of groundwater contamination. This conclusion is also discussed in the Field and Laboratory Investigation Report.

Comment 5: The State noted several inconsistencies and contradictions between data presented in the Draft Assessment and the Task 24 Final Phase I Army Spill Sites Data Presentation Report for the South Plants Manufacturing Complex (9/89), as well as the South Plants Study Area Report (SPSAR, 6/89). These inconsistencies and contradictions are further discussed in the specific comments below. These problems should be acknowledged in this report and resolved as soon as possible, if necessary with additional field studies.

Response: Any inconsistencies will be addressed under the specific comments.

SPECIFIC COMMENTS

Comment 1: Page 1-3 & 1-4 - The candidate selection criteria discussed on pages 1-3 & 1-4 do not accord with the flow chart presented as Figure 1-2. Specifically, the flow chart's initial diamond which presents the threshold question of whether the site is an active, primary source of contamination does not limit that question to an assessment of the site's effect on ground water. Such a limitation was expressly disapproved by State representatives at the June 7, 1989 subcommittee meeting which was held to discuss screening criteria for the "other sources" IRA.

Secondly, the first bullet under the third criteria, which is suppose to accord with the third diamond on the chart should be changed to address the question of accelerated clean-up. The question currently posed: "Will interim action reduce risks?" is vague and undefined and should more appropriately be applied as an evaluation criteria by which to judge proposed remedial alternatives.

Response: The fact that the M-1 Settling Basins contain a lime sludge contaminated with high concentrations of arsenic is well known from historical data and previous studies. The basins have been covered since about 1947 with soil and/or structures (concrete pads and tanks). The Army did not limit its analysis to the site's effect on groundwater; however, since the contaminated sludge is below grade and has been covered with soil/structures for approximately 40 years, air emissions from the sludge are considered unlikely. The dirt road across the site and structures presents limited contact with burrowing animals and the site is not vegetated so impacts on biota are not considered significant. The Army's major concern and the emphasis of this assessment is the threat of release of arsenic contamination to the groundwater from the M-1 Settling Basins.

Secondly, the Army agrees that adding a statement on accelerated cleanup would clarify the discussion on page 1-4 and the text has been changed. The major risk at this site is the threat of release of contamination from the M-1 Settling Basins to the groundwater. Accelerated cleanup would reduce that risk.

Comment 2: Page 1-4 - The benefit in performing an interim action to remediate a source under the "Other Sources" IRA should be analyzed in the Alternative Assessment Document, not in the Decision Document as proposed by the Army. Unless such a benefit is recognized, the Army should not be expending time and resources evaluating alternatives.

Response: Agreed. The benefit in performing an IRA is discussed in the expanded evaluation presented in Section 6.0.

Comment 3: Page 3-1 - The introductory paragraph indicates that an interim action objective is to treat "the soil and groundwater to protect human health and the environment" (emphasis added). In other portions of the report the Army has stated that this IRA will not address groundwater remediation. These contradictory statements must be reconciled.

Response: The text of this paragraph has been changed. Groundwater treatment in the vicinity of the M-1 Settling Basins is beyond the scope of this IRA.

Comment 4: Page 3-15 - It is not clear why the Army has limited offsite alternatives to chemical fixation/stabilization. This choice must be explained and justified.

Response: Because the M-1 Settling Basins were used to treat waste fluids from the lewisite disposal facility, there is some possibility that some lewisite or breakdown products may exist in the basins. This possibility precludes the feasibility of taking untreated M-1 Settling Basins sludges offsite for treatment.

Comment 5: Page 3-16: - In section 3.2.5.4.1, the Army states that off-site chemical fixation/stabilization "utilizes readily available materials and equipment, is technically feasible, and will be considered further"; however, it is not evaluated in chapters 4 and 5, nor is it ranked in chapter 6. The report should be revised, therefore, to include a detailed evaluation of this alternative.

Response: The text has been changed to state that this is technically feasible. It will not necessarily be considered further. This technology was not included in an alternative because of the preference to treat on site, as discussed in Section 1.1.

Comment 6: Page 3-17 & 4-9 - A hazardous waste landfill must also meet the requirements of 6 CCR 1007-3 section 264 subpart N and 6 CCR 1007-2. Even a cursory review of State siting requirements indicates that a hazardous waste landfill could not be located in the vicinity of the M-1 ponds; therefore, this alternative should be eliminated from further consideration.

In addition, the construction of a landfill is not appropriately conducted under an IRA and may be inconsistent with the final remedy selected for the entire Arsenal. Any residual wastes must either be disposed of off site or temporarily stored in a waste pile.

Response: The onsite landfill discussed in this Alternatives Assessment is intended to be used for temporary storage until re-evaluation during final remediation. The text has been changed to clarify this point. The term "onsite landfill" has been replaced with "temporary waste pile." The location of the temporary waste pile would be chosen during implementation. The waste pile would be constructed to meet ARARs to the maximum extent practicable.

Comment 7: Page 3-17 - The Army would also need to comply with State regulations regarding the landfilling of solid waste. See 6 CCR 1007-2.

Response: Acknowledged. Construction of an onsite temporary wastepile would comply with ARARs to the maximum extent practicable.

Comment 8: Page 3-18 - If the shallow aquifer is in contact with contaminated material within the basins, as it appears to be, dewatering will be necessary to ensure complete excavation and proper treatment of the basin materials. Unless all of the contaminated materials are effectively removed from the basins or treated, they will continue to contaminate the underlying ground water.

Response: Agreed. Decisions on dewatering and water treatment methods, if necessary, would be made during design. A distinct advantage to in situ vitrification is that any water encountered during operation would essentially be "boiled off" and condensed in the offgas collection and treatment system. Any associated organic contaminants would be pyrolyzed in the melt.

Comment 9: Page 3-28 - In section 3.2.7.3.1, the Army rejects as a treated water disposal alternative, the reinjection of extracted water into aquifers underneath the Arsenal, yet this method has been chosen not only at the boundary systems, but also for other IRAs such as the north of Basin F intercept and the Basin A Neck intercept systems. This report should explain why a technology chosen for these other response actions is inappropriate under the circumstances of this IRA.

Response: The Army screens out the use of wells for reinjection because of potential fouling problems. Reinjection through percolation beds or trenches is considered. The text has been revised to clarify this point. Decisions on dewatering and water treatment methods, if necessary, would be made during design.

Comment 10: Page 3-29 - In section 3.2.7.3.3, the Army points out the problems that would be created by disposing of treated water into the sanitary sewers. The State has previously raised these concerns in relation to Army proposals to discharge CERCLA wastewater, hydrazine wastewater and 1727 liquids into this system; however, these concerns have been ignored. Why are the problems identified in this section not of concern for the other IRAs?

The report should also evaluate the possibility of routing the dewatered fluids to the CERCLA wastewater treatment facility.

Response: The State is incorrect in saying that the Army has proposed the direct discharge of any RMA wastewaters into the sanitary sewer. The discharge of wastewater only after treatment to levels specified by ARARs has been proposed for other IRAs, i.e. CERCLA Liquid Waste, Hydrazine Facility, and Building 1727 Sump. The intent of Section 3.2.7.3.3 was not to point out problems, which the Army does not foresee, but to point out the minimal requirements of treatment prior to discharge into the sanitary sewer. Concerns regarding the CERCLA wastewater treatment facility, the Hydrazine IRA, and the 1727 Sump IRA have been addressed in the documentation for those actions and in revisions to the NPDES permit. The State's assertion that, "these concerns have been ignored" is incorrect. A significant distinction in considering treatment of wastewater from this IRA is the potential high arsenic concentration.

Use of the proposed CERCLA wastewater treatment plant for groundwater treatment was not evaluated in this IRA Alternatives Assessment because the treatment plant is still in development. Should dewatering and water treatment be necessary, options such as those described in Section 3.2.7 or any new options such as the CERCLA Wastewater Treatment Plant would be considered during the design and implementation of this IRA.

Comment 11: Page 3-20 - The discussions of water treatment processes contained in Section 3.2.7.2 do not include projections of the water quality to be achieved by each technology; nor does the Draft ARARs document set ARARs or remedial action objectives for the organics that have been detected in the ground water underlying the basins. Without knowing the effectiveness of each treatment process, the parties cannot assess the alternatives in accordance with the ARARs and protectiveness evaluation criteria.

Response: It is not the intent of this alternatives assessment to set effluent water quality standards or objectives. Water treatment technologies were screened based on their ability to treat high concentrations of organics in water. If any water treatment is necessary, the process(es) would be designed to meet all ARARs identified.

Comment 12: The description of alternative 7 does not indicate whether chemical fixation will result in a material which would be classified as a hazardous waste; thus, it is not clear whether the landfill described would be a solid waste or hazardous waste unit. As noted in specific comment 6 above, a hazardous waste landfill at RMA, especially in the vicinity of the M-1 Settling Basins, would not meet the State's siting requirements for hazardous waste disposal facilities.

Response: The onsite landfill discussed in this alternatives assessment is meant to be for temporary storage of the treated materials until the final remedy. The text has been changed to clarify this by replacing the term "landfill" with "temporary waste pile." The location of the waste pile would be chosen during implementation. The waste pile would be constructed according to ARARs, to the maximum extent practicable.

Comment 12: Table 4-1a - This table indicates that an onsite wastepile would not comply with requirements for detection monitoring but does not explain why the Army would not perform such monitoring. Any on-site landfill must comply with the appropriate State and federal requirements regarding groundwater monitoring.

Response: See response to the State's first Specific Comment No. 12. It was assumed, for the purposes of this alternatives assessment, that groundwater monitoring would be performed using existing monitoring wells rather than constructing new wells because the waste pile is for temporary storage. The need for additional monitoring wells will be assessed during implementation.

Comment 13: Page 6-2 - Offsite disposal is not significantly more expensive than in-situ vitrification and should therefore be considered a preferred alternative. Potential liability is not an evaluation

criteria recognized by CERCLA, the NCP, the Federal Facility Agreement or the Task Plan for the Remediation of Other Sources IRA which was finalized this past Spring. Besides, should Grassy Mountain ever become subject to CERCLA remedial action, the Army is already a potentially responsible party for that cleanup since they previously arranged for the disposal of 78,000 barrels of RMA hazardous wastes at that facility in 1986. The potential and extent of liability can be minimized by complying fully with all federal and State regulations regarding the transportation and disposal of hazardous wastes.

Response: Cost was not the only criteria used to evaluate whether an alternative is preferred, marginally preferred, or not preferred. As stated on page 6-1 of the Draft Final Assessment, "Marginally preferred alternatives meet the threshold criteria listed in Table 4-1a to some degree and meet some of the evaluation criteria listed in Table 4-1b." The criteria of 4-1b, in addition to cost, include implementability, long-term effectiveness, short-term effectiveness, and reduction of mobility, toxicity, and volume. There is also an express CERCLA preference for onsite treatment. The Army agrees that potential liability is not an evaluation criteria; it is only an aspect of long-term effectiveness. The state should note that all preferred and marginally preferred alternatives are considered further in the decision process. Offsite disposal is therefore considered further.

Comment 14: Many of the treatment technologies described in this alternative assessment cannot be adequately evaluated without site-specific treatability studies. This is particularly true for the in-situ treatment technologies, the ability of which to achieve the protectiveness criteria described in Section 4.2 can only be ascertained with bench or pilot testing. These activities are invariably time consuming, yet they are necessary for an accurate assessment of feasibility and effectiveness. The report does not acknowledge these realities; therefore, it must be modified to include these considerations when assessing "implementability" and scheduling.

Response: Bench scale testing of both ISV and chemical fixation has already been performed. Results of these tests are presented in the Field and Laboratory report (WCC 1989). In order to proceed with the ISV, about six additional borings would need to be drilled and soil samples taken to evaluate a more exact depth of contamination. This could be done during the design phase of the IRA. No additional pilot testing is required. For chemical fixation, additional sludge/soil samples would be sent to vendors during the bidding process. This could also be done during the design phase of the IRA.

Comment 15: As discussed in general comment number 5, the State has noted several difficulties with the source characterization data presented in this report, and in those reports referenced in comment 5. These difficulties include the following:

A) As-built drawings of the three unlined basins on site indicate that basin dimensions are 115 x 90 x 7 ft³ (Alternative Assessment Document, page 2-1). Assuming a total surface area of 115 x 300 ft², or 34,500 ft² (Table 2-4), this results in a total sludge volume of 9,000 yd³. The site was regraded in 1947, and covered with 2-to-4 feet of imported soil (page 2-2), which translates to a basin-bottom depth of 9-to-11 feet below land surface. However, in a volume calculation presented on page 2-15 and in Table 2-4, the Army assumed that "waste material extended to a depth of seven feet below ground surface". Subtracting an assumed two foot thickness of imported soils resulted in a total sludge volume of 6,400 yd³. This calculation, therefore, is not based on the seven foot thickness of the basins as indicated in the as-built drawings, but an erroneous five foot thickness. The basin dimensions of 115 x 90 x 7 ft³ also differ from the 100 x 75 x 5 ft³ basin dimensions presented in the Army Spill Sites Report (page 8).

B) The Alternative Assessment Document (page 2-4) states that six soil borings were completed in and around the perimeter of the M-1 Settling basins. However, the referenced figure (Figure 2-1) actually shows eight soil borings and there is no cross-referencing between the text and figure to clarify this discrepancy. The number system for the eight borings is also not consistent with the borings presented in the Army Spill Sites Report I (Plate 24S-1). Only three borings were completed in this study; two additional borings were not analyzed due to the presence of lewisite. Because basin perimeters are not marked on Plate 24S-1, it is difficult to determine coring locations with respect to the pits. However, it appears that only one boring (Boring 4) may have actually been completed within a basin. Nowhere in the text is there an indication that the bottom of any of the three basins was encountered.

The SPSAR states that only one of three borings in the Task 24 Army Spills program was completed. This contradicts the data presented in the Spill Sites Report. The SPSAR also states that additional borings completed by the Army and Shell (no reference given) were only completed to five feet below land surface, and did not reach the bottom of the basins. The soil boring locations presented in Figure SPSA 1.4-2 do not match either those presented on Plate 24S-1 of the Spill Sites Report, or Figure 2-1 of the Alternative Assessment Document.

C) In addition to the above discrepancies, data presented in the M-1 Basins Alternative Assessment Document are ambiguous. Table 2-1 presents a summary of contaminants in soils and sludge, but does not correlate soil boring number/location and sample depth with contaminant concentration, or indicate from which of the two references (D.P. Associates, Inc., 1989a; Ebasco Services, Inc., 1988) the data were cited. Because of the inconsistencies between the three reports with respect to boring locations/numbers, it is impossible to validate or invalidate Table 2-1 entries.

D) In the groundwater contamination summary presented in Table 2-2, well numbers/locations are not correlated to sampling episode, contaminant concentration, or a cited source (D.P. Associates, Inc., 1986; D.P. Associates Inc. 1989b). The data appear to be from alluvial wells 01503, 01504, 01077, 01083, 01524, 36001, and 36193 as shown in Figure 1-1, but this is not stated in the text or table. The Army must furnish actual well numbers referenced in the table.

If these seven wells do comprise all wells from which the data were compiled in Table 2-2, then data gaps exist. Wells 01503 and 01504 appear to have been sampled for volatiles, semi-volatiles, and pesticides prior to 1984 only; current data are not available. New wells 36193 and 01083 are not being monitored in the Comprehensive Monitoring Program (CMP), and therefore data for the above analyte groups are also not available for these wells. Well 01077 is not listed in the RMA Groundwater Chemical Data Base as of 12/88.

Response:

(A) The as-built drawings show the three M-1 Settling Basins each to be 115 feet by 90 feet by 7 feet deep. The 7-foot depth consists of 5 feet of sludge in the bottom of the basins, and 2 feet of soil overburden. Soil borings taken during the 1989 field investigation confirmed the depth of the sludge (WCC 1989). We noticed the discrepancy with the Army Spill Sites Report, and chose to use the as-built drawings for the evaluation basis.

(B) Figure 2-1 has been corrected to show the six soil borings drilled during previous investigations. Three were drilled during the Army Spill Sites investigation. The other three were drilled in 1986 and the data are in the RMA data base. The data from these borings are summarized in Table 2-1.

Discrepancies between the South Plants SAR and the Army Spill Sites Report were not addressed. Data from the Army Spill Sites Report were used in this Alternatives Assessment. The discrepancies do not affect the conclusions or recommendations of this alternatives assessment.

(C) Table 2-1 is intended to summarize the contaminants found in the M-1 Settling Basins sludge, and the soil surrounding above, and beneath the sludge. Data from the two references cited were used, as well as data from the 1989 field investigation (WCC 1989). Please see the RMA data base, the Ebasco report, and the WCC report for additional details.

(D) The upgradient and downgradient well numbers have been added to Table 2-1. The table is intended to present a summary of contaminants found in the groundwater; not a detailed analysis.

The data from these seven wells are enough to show that the M-1 Settling Basins are a source of groundwater contamination. These wells would also be sufficient for future monitoring activities to provide information on groundwater contamination trends influenced by the M-1 Settling Basins.

Comment 16: Additional characterization of the source is needed before an appropriate alternative can be selected and implemented. Site characterization should consist of data collection designed to determine:

- A) more precise dimensions of the M-1 Settling Basins;
- B) thickness of overlying soils;
- C) lateral and vertical extent of soils and sludge contamination; and
- D) interaction of alluvial groundwater with basin contaminants.

Response: The Army believes sufficient data is available to support an assessment of alternatives. The Army disagrees with the State's assumption that significant additional characterization is required at the site. Additional characterization is inconsistent with the spirit of an Interim Response Action, which is intended to respond to a contamination source in an expeditious manner. Some additional site characterization may be necessary for some alternatives during the design phase of the IRA, specifically to identify more exact lateral and vertical extent of soils and sludge contamination.



United States Department of the Interior

FISH AND WILDLIFE SERVICE

COLORADO FIELD OFFICE

730 SIMMS STREET

ROOM 202

GOLDEN, COLORADO 80401

IN REPLY REFER TO:

11 1989

FWE/CO

Mr. Donald L. Campbell
Office of Program Manager
Building 111
Rocky Mountain Arsenal
Commerce City, CO 80022

Dear Mr. Campbell:

We have reviewed the following documents and have no comments on them at this time: (1) Rocky Mountain Arsenal Offpost Private Well Inventory and Information Survey; (2) the Draft Final Assessment Reports for the M-1 Basins Section one and the Motor Pool area in Section 4 of the Rocky Mountain Arsenal; (3) and, the Applicable, Relevant and Appropriate Regulations (ARAR's) pertaining to these sites.

We appreciate the opportunity to review and comment on the documents.

Sincerely,

Wm. R. Noonan

for

LeRoy W. Carlson
Colorado State Supervisor

cc: Pete Gober, FWS
Tom Jackson, FWS
Bob Stewart, DOI
David Anderson, DOJ
Connally Mears, EPA